Tech
F

THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

111

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Prof. Edwin J. Houston, A.M., Ph.D., Mr. Theo. D. Rand, Prof. Coleman Sellers, E.D., Prof. H. W. Spangler, Mr. J. C. Trautwine, Jr., C.E., Committee on Publications, with the Assistance of Dr. Wm. H. Wahl, Secretary of the Institute.

VOL. CXXXVI.—Nos. 811-816.

JULY-DECEMBER, 1893.

PHILADELPHIA:
Published by the Institute, at the Hall, 15 South Seventh Street.
1893.

JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXXXVI.—July-December, 1893.

INDEX.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXVI. JULY, 1893. NO. 1

ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA.*

BY NIKOLA TESLA.

INTRODUCTORY.

Some Thoughts on the Eye.—When we look at the world around us, on nature, we are impressed with its beauty and grandeur. Each thing we perceive, though it may be vanishingly small, is in itself a world; each, like the whole visible universe, is a world of matter and force governed by law—a world, the contemplation of which fills us with feelings of wonder and irresistibly urges us to ceaseless thought and inquiry. But in all this vast world, of all the objects our senses reveal to us, the most marvellous,

* A lecture delivered before the Franklin Institute, at Philadelphia, February 24, 1893, and before the National Electric Light Association, at St. Louis, March 1, 1893.

the most appealing to our imagination, appears no doubt in highly developed organism, a thinking being. If there is anything fitted to make us admire nature's handiwork, it is certainly this inconceivable structure, which performs its innumerable motions in obedience to external influence. To understand its workings, to get a deeper insight into this nature's masterpiece, has ever been for thinkers a fascinating aim, and after many centuries of arduous research men have arrived at a fair understanding of the functions of its organs and senses. Again, in all the perfect harmony of its parts, of the parts which constitute the material or tangible of our being, of all its organs and senses, the eye is the most wonderful. It is the most precious, the most indispensable of our receptive or directive organs, it is the great gateway through which all knowledge enters the mind. Of all our organs, it is the one which is in the most intimate relation with that which we call intellect. So intimate is this relation, that it is often said, the very soul shows itself in the eye.

It can be taken as a fact, which the theory of the action of the eye implies that for each external impression; that is, for each image produced upon the retina, the ends of the visual nerves concerned in the conveyance of the impression to the mind, must be under a peculiar stress or in a vibratory state. It now does not seem improbable that, when by the power of thought an image is evoked, a distinct reflex action, no matter how weak, is exerted upon certain ends of the visual nerves, and therefore upon the retina. Will it ever be within human power to analyze the condition of the retina when disturbed by thought or reflex action, by the help of some optical or other means of such sensitiveness, that a clear idea of its state might be gained at any time? If this were possible, then the problem of reading one's thoughts with precision, like the characters of an open book, might be much easier to solve than many problems belonging to the domain of positive physical science, in the solution of which many, if not the majority, of scientific men implicitly believe. Helmholtz has shown that the fundi of the eyes are themselves luminous, and he

was able to *see*, in total darkness, the movement of his arm by the light of his own eyes. This is one of the most remarkable experiments recorded in the history of science, and probably only a few men could satisfactorily repeat it, for it is very likely that the luminosity of the eyes is associated with uncommon activity of the brain and great imaginative power. It is fluorescence of brain action, as it were.

There is another fact bearing on this subject, which has probably been noted by many, since it is stated in popular expressions, but which I cannot recollect to have found chronicled as a positive result of observation, viz: that at times, when a sudden idea or image presents itself to the intellect, there is a distinct and sometimes painful sensation of luminosity produced in the eye, and observable even in broad daylight.

The saying, then, that the soul shows itself in the eye, is deeply founded, and we feel that it expresses a great truth. It has a profound meaning even for one who, like a poet or artist, following only his inborn instinct or love for nature, finds delight in aimless thoughts and in the mere contemplation of natural phenomena, but a still more profound meaning for one who, in the spirit of positive scientific investigation, seeks to ascertain the causes of the effects. It is the natural philosopher, the physicist, for whom the eye is the subject of the most intense admiration.

Two facts about the eye must forcibly impress the mind of the physicist, notwithstanding he may think or say that it is an imperfect optical instrument, forgetting that the very conception of that which is perfect, or seems so to him, has been gained through this same instrument. Firstly, the eye is, as far as our positive knowledge goes, the only organ which is *directly* affected by that subtile medium, which as science teaches us, must fill all space; secondly, it is the most sensitive of our organs, incomparably more sensitive to external impressions than any other.

The organ of hearing requires the impact of ponderable bodies, the organ of smell the transference of detached material particles, and the organs of taste, and of touch or

force, the direct contact, or at least some interference of ponderable matter, and this is true even in those instances of animal organisms, in which some of these organs are developed to a degree of truly marvellous perfection. This being so, it seems wonderful that the organ of sight alone should be capable of being stirred by that which all our other organs are powerless to detect, which yet plays an essential part in all natural phenomena, which transmits all energy and sustains all motion and life, but which has properties such that even a scientifically trained mind cannot help drawing a distinction between it and all that is called matter. Considering merely this, and the fact that the eye, by its marvellous power, widens our otherwise very narrow range of perception far beyond the limits of the small world which is our own, and enables it to embrace myriads of other worlds, suns and stars in the infinite depths of the universe, it would seem justifiable to assert that the eye is an organ of a higher order than others. Its performances are beyond comprehension. Nature, as far as we know, never produced anything more wonderful. We can get barely a faint idea of its prodigious power by analyzing what it does and by comparing. When ether waves impinge upon the human body, they produce the sensations of warmth or cold, pleasure or pain, or perhaps other sensations of which we are not aware, and any degree or intensity of these sensations, which degrees are infinite in number, hence an infinite number of distinct sensations. But our sense of touch, or our sense of force, cannot reveal to us these differences in degree or intensity, unless they are very great. Now we can readily conceive how an organism, such as the human in the eternal process of evolution, or more philosophically speaking, adaptation to nature, being constrained to the use of only the sense of touch or force, for instance, might develop this sense to such a degree of sensitiveness or perfection, that it would be capable of distinguishing the minutest differences in the temperature of a body even at some distance, to a hundredth, or thousandth, or millionth part of a degree. Yet even this apparently impossible performance would not begin to compare with that of the

eye, which is capable of distinguishing and conveying to the mind in a single instant innumerable peculiarities of the body, be it in form or color or other respects. This power of the eye rests upon two things, namely, the rectilinear propagation of the disturbance by which it is affected, and its sensitiveness. To say that the eye is sensitive is not saying anything. Compared with it all other organs are monstrously crude. The organ of smell which guides a dog on the trail of a deer, the organ of touch or force which guides an insect in its wanderings, the organ of hearing, which is affected by the slightest disturbances of the air, are sensitive organs, to be sure, but what are they compared with the human eye? No doubt it responds to the faintest echoes or reverberations of the medium; no doubt, it brings us tidings from other worlds, infinitely remote, but in a language we cannot as yet always understand. And why not? Because we live in a medium filled with air and other gases and vapors and a dense mass of solid particles flying about. These play an important part in many phenomena; they fritter away the energy of the vibrations before they can reach the eye; they, too, are the carriers of germs of destruction, they get into our lungs and other organs, clog up the channels, and imperceptibly yet inevitably arrest the stream of life. Could we but do away with all ponderable matter in the line of sight of the telescope, it would reveal to us umdreamt-of marvels. Even the unaided eye, I think, would be capable of distinguishing in the pure medium, small ojects at distances measured probably by hundreds or perhaps thousands of miles.

But there is something else about the eye which impresses us still more than these wonderful features which we observe, viewing it from the standpoint of a physicist, merely as an optical instrument—something which appeals to us more than its marvellous faculty of being directly affected by the vibrations of the medium, without interference of gross matter, and more than its inconceivable sensitiveness and discerning power. It is its significance in the processes of life. No matter what one's views of nature and life may be, he must stand amazed when, for the first time in his

thoughts, he realizes the importance of the eye in the physical processes and mental performances of the human organism. And how could it be otherwise, when he realizes that the eye is the means through which the human race has acquired the entire knowledge it possesses, that it controls all our motions, more still, all our actions.

There is no way of acquiring knowledge except through the eye. What is the foundation of all philosophical systems of ancient and modern times; in fact, of all the philosophy of man? *I am, I think; I think; therefore, I am.* But how could I think and how would I know that I exist if I had not the eye? For knowledge involves consciousness; consciousness involves ideas, conceptions; conceptions involve pictures or images, and images the sense of vision, and, therefore, the organ of sight. But how about blind men, will be asked? Yes, a blind man may depict in magnificent poems forms and scenes from real life, from a world he physically does not see. A blind man may touch the keys of an instrument with unerring precision, may build the fastest boat, may discover and invent, calculate and construct, may do still greater wonders—but all the blind men who have done such things have descended from those who had seeing eyes. Nature may reach the same result in many ways. Like a wave in the physical world, in the infinite ocean of the medium which pervades all, so in the world of organisms, in life, an impulse started proceeds onward, at times, may be, with the speed of light, at times, again, so slowly, that for ages and ages it seems to stay, passing through processes of a complexity inconceivable to men, but in all its forms, in all its stages, its energy ever and ever integrally present. A single ray of light from a distant star falling upon the eye of a tyrant in by-gone times, may have altered the course of his life, may have changed the destiny of nations, may have transformed the surface of the globe, so intricate, so inconceivably complex are the processes in nature. In no way can we get such an overwhelming idea of the grandeur of nature as when we consider that in accordance with the law of the conservation of energy, throughout the infinite, the forces are

in a perfect balance, and hence the energy of a single thought may determine the motion of a universe. It is not necessary that every individual, not even that every generation or many generations, should have the physical instrument of sight, in order to be able to form images and to think; that is, to form ideas or conceptions; but at some time or other, during the process of evolution, the eye certainly must have existed; else thought, as we understand it, would be impossible; else conceptions, like spirit, intellect, mind, call it as you may, could not exist. It is conceivable, that in some other world, in some other beings, the eye is replaced by a different organ, equally or more perfect, but these beings cannot be men.

Now, what prompts us to all voluntary motions and actions of any kind? Again, the eye. If I am conscious of the motion, I must have an idea or conception; that is, an image; therefore the eye. If I am not precisely conscious of the motion, it is because the images are vague or indistinct, being blurred by the superimposition of many. But when I perform the motion, does the impulse which prompts me to the action come from within or from without? The greatest physicists have not disdained to endeavor to answer this and similar questions, and have at times abandoned themselves to the delights of pure and unrestrained thought. Such questions are generally considered not to belong to the realm of positive physical science, but before long they will be annexed to its domain. Helmholtz has probably thought more on life than any other modern scientist. Lord Kelvin expressed his belief that life's process is electrical and that there is a force inherent in the organism and determining its motions. Just as much as I am convinced of any physical truth, I am convinced that the motive impulse must come from the outside. For, consider the lowest organism we know—and there are probably many lower ones—an aggregation of a few cells only. If it is capable of voluntary motion it can perform an infinite number of motions, all definite and precise. But now a mechanism consisting of a finite number of parts and a few at that, cannot perform an infinite number of definite motions; hence the impulses

which govern its movements must come from the environment. So, the atom, the ulterior element of the universe's structure, is tossed about in space eternally, the toy of external influences, like a float in a troubled sea. Were it to stop its motion *it would die*. Matter at rest, if such a thing could exist, would be matter dead. Death of matter! Never has a sentence of deeper philosophical meaning been uttered. This is the way in which Professor Dewar forcibly expresses it in the description of his admirable experiments, in which liquid oxygen is handled as one handles water, and air at ordinary pressure is made to condense and even to solidify by the intense cold: experiments, which serve to illustrate, as he says, the last feeble manifestations of life, the last quiverings of matter about to die. But human eyes shall not witness such death. There is no death of matter, for throughout the infinite universe, all has to move, to vibrate; that is, to live.

I have made the preceding statements at the peril of treading upon metaphysical ground in my desire to introduce the subject of this lecture in a manner not altogether uninteresting, I may hope, to an audience such as I have the honor to address. But now, then, returning to the subject, this divine organ of sight, this indispensable instrument for thought and all intellectual enjoyment, which lays open to us the marvels of this universe, through which we have acquired what knowledge we possess, and which prompts us to, and controls, all our physical and mental activity. By what is it affected? By light! What is light?

We have witnessed the great strides which have been made in all departments of science in recent years. So great have been the advances that we cannot refrain from asking ourselves, Is this all true, or is it but a dream? Centuries ago men lived, thought, discovered, and invented, and they believed that they were soaring, while they were merely proceeding at a snail's pace. So we, too, may be mistaken. But taking the truth of the observed events as one of the implied facts of science, we must rejoice in the immense progress already made and still more in the anticipation of what must come, judging from the

possibilities opened up by modern research. There is, however, an advance which we have been witnessing, which must be particularly gratifying to every lover of progress. It is not a discovery, or an invention, or an achievement in any particular direction. It is an advance in all directions of scientific thought and experiment. I mean the generalization of the natural forces and phenomena, the looming up of a certain broad idea on the scientific horizon. It is this idea, which, however, long ago took possession of the most advanced minds, to which I desire to call your attention, and which I intend to illustrate, in a general way, in these experiments, as the first step in answering the question, "What is light?" and to realize the modern meaning of this word.

It is beyond the scope of my lecture to dwell upon the subject of light in general, my object being merely to bring presently to your notice a certain class of light effects and a number of phenomena observed in pursuing the study of these effects. But to be consistent in my remarks, it is necessary to state that according to that idea, now accepted by the majority of scientific men as a positive result of theoretical and experimental investigation, the various forms or manifestations of energy which were generally designated as "electric" or more precisely "electro-magnetic" are energy manifestations of the same nature as those of radiant heat and light. Therefore, the phenomena of light and heat, and others besides these, may be called electrical phenomena. Thus, electrical science has become the mother science of all and its study has become all important. The day when we shall know exactly what "electricity" is, will chronicle an event probably greater, more important, than any other recorded in the history of the human race. The time will come when the comfort, perhaps the very existence, of man will depend upon that wonderful agent. For our existence and comfort we require heat, light and mechanical power. How do we now get all these? We get them from fuel, we get them by consuming material. What will man do when the forests disappear; when the coal fields are exhausted? Only one

thing, according to our present knowledge, will remain; that is, to transmit power at great distances. Men will go to the waterfalls, to the tides, which are the stores of an infinitesimal part of nature's immeasurable energy. There will they harness the energy and transmit the same to their settlements, to warm their homes, to give them light and to keep their obedient slaves, the machines, toiling. But how will they transmit this energy if not by electricity? Judge then, if the comfort, nay, the very existence of man, will not depend on electricity. I am aware that this view is not that of a practical engineer, but neither is it that of an illusionist, for it is certain, that power transmission, which at present is merely a stimulus to enterprise, will some day be a dire necessity.

It is more important for the student who takes up the study of light phenomena, to make himself thoroughly acquainted with certain modern views, than to peruse entire books on the subject of light itself, as disconnected from these views. Were I therefore to make these demonstrations before students seeking information—and for the sake of the few of these who may be present, give me leave to so assume—it would be my principal endeavor to impress these views upon their minds in this series of experiments.

It might be sufficient for this purpose to perform a simple and well-known experiment. I might take a familiar appliance, a Leyden jar, charge it from a frictional machine, and then discharge it. In explaining to you its permanent state when charged, and its transitory condition when discharging, calling your attention to the forces which enter into play and to the various phenomena they produce, and pointing out the relation of the forces and phenomena, I might fully succeed in illustrating that modern idea. No doubt, to the thinker, this simple experiment would appeal as much as the most magnificent display. But this is to be an experimental demonstration, and one which should possess besides instructive, also entertaining features; and as such, a simple experiment, such as the one cited, would not go very far towards the attainment of the lecturer's aim. I must therefore choose another way of illustrating, more

spectacular certainly, but perhaps also more instructive. Instead of the frictional machine and Leyden jar, I shall avail myself in these experiments of an induction coil of peculiar properties, which was described in detail by me in a lecture before the London Institution of Electrical Engineers, in February, 1892. This induction coil is capable of yielding currents of enormous potential differences, alternating with extreme rapidity. With this apparatus I shall endeavor to show you three distinct classes of effects, or phenomena, and it is my desire that each experiment, while serving for the purposes of illustration, should at the same time teach us some novel truth, or show us some novel aspect of this fascinating science. But before doing this, it seems proper and useful to dwell upon the apparatus employed, and upon the method of obtaining the high potentials and high frequency currents which are made use of in these experiments.

On the Apparatus and Method of Conversion.—These high frequency currents are obtained in a peculiar manner. The method employed was advanced by me about two years ago in an experimental lecture before the American Institute of Electrical Engineers. A number of ways, as practised in the laboratory, of obtaining these currents either from continuous or low frequency alternating currents is diagrammatically indicated in *Fig. 1*, which will be later described in detail. The general plan is to charge condensers, from a direct or alternate current source, preferably of high tension, and to discharge them disruptively while observing well-known conditions necessary to maintain the oscillations of the current. In view of the general interest taken in high frequency currents and in the effects producible by them, it seems to me advisable to dwell at some length upon this method of conversion. In order to give you a clear idea of the action, I will suppose that we employ a continuous current generator which is often very convenient. It is desirable that the generator should possess such high tension as to be able to break through a small air space. If this is not the case, then auxiliary means have to be resorted to, some of which will be indicated subsequently. When the conden-

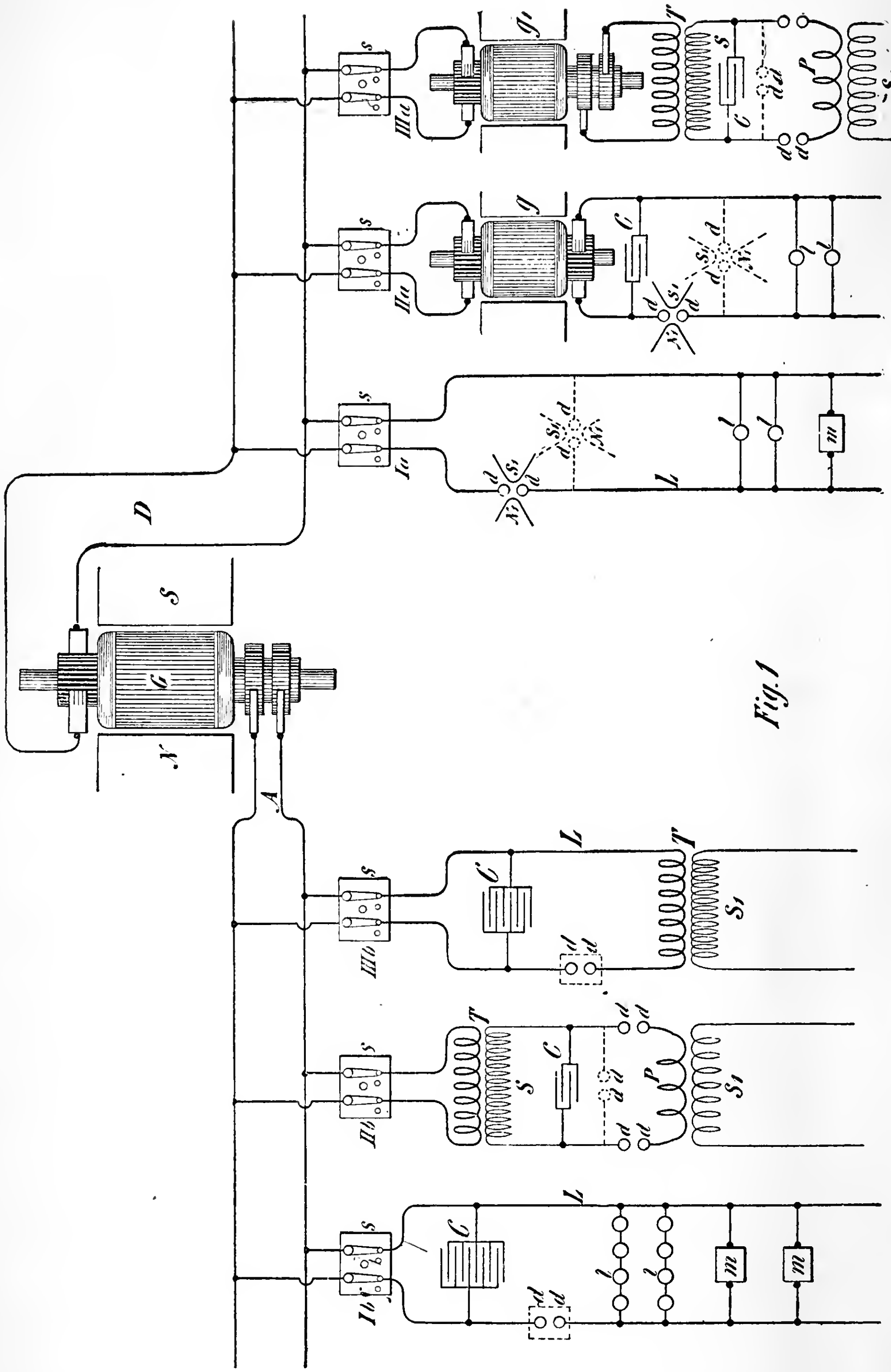


FIG. 1.—Plan of connection used in the conversion by means of the disruptive arc discharge.

sers are charged to a certain potential, the air or insulating space gives way and a disruptive discharge occurs. There is then a sudden rush of current and generally a large portion of

the accumulated electrical energy spends itself. The condensers are thereupon quickly charged and the same process is repeated in more or less rapid succession. To produce such sudden rushes of current it is necessary to observe certain conditions. If the rate at which the condensers are discharged is the same as that at which they are charged, then, clearly, in the assumed case the condensers do not come into play. If the rate of discharge be smaller than the rate of charging, then, again, the condensers cannot play an important part. But if, on the contrary, the rate of discharging is greater than that of charging, then a succession of rushes of current is obtained. It is evident that if the rate at which the energy is being dissipated by the discharge is very much greater than the rate of supply to the condensers, the sudden rushes will be comparatively few, with long-time intervals between. This always occurs when a condenser of considerable capacity is charged by means of a comparatively small machine. If the rates of supply and dissipation are not widely different, then the rushes of current will be in quicker succession, and the more so, the more nearly equal both rates are, until natural limitations, incident to each case and depending upon a number of causes, are reached. Thus we are able to obtain from a continuous current generator as rapid a succession of discharges as we like. Of course, the higher the tension of the generator, the smaller need be the capacity of the condensers, and for this reason, principally, it is of advantage to employ a generator of very high tension. Besides, such a generator permits the attaining of greater rates of vibration.

The rushes of current may be of the same direction under the conditions before assumed, but most generally there is an oscillation superimposed upon the fundamental vibration of the current. When the conditions are so determined that there is no oscillation, the current impulses are unidirectional and thus a means is provided of transforming a continuous current of high tension into a direct current of lower tension, which I think may find employment in the arts.

This method of conversion is exceedingly interesting, and

I was much impressed by its beauty when I first conceived it. It is ideal in certain respects. It involves the use of no mechanical devices of any kind, and it allows of obtaining currents of any desired frequency from an ordinary circuit, direct or alternating. The frequency of the fundamental discharges, depending as it does on the relative rates of supply and dissipation, can readily be varied within wide limits by simple adjustments of these quantities, and the frequency of the superimposed vibration by the determination of the capacity, self-induction and resistance of the circuit. The potential of the currents, again, may be raised as high as any insulation is capable of withstanding safely, by combining capacity and self-induction, or by induction in a secondary, which need have but comparatively few turns.

As the conditions are often such that the intermittence or oscillation does not readily establish itself, especially when a direct current source is employed, it is of advantage to associate an interrupter with the arc, and I indicated, some time ago, the use of an air-blast or magnet, or other such device readily at hand. The magnet is employed with special advantage in the conversion of direct currents, as it is then very effective. If the primary source is an alternate current generator, it is desirable, as I stated on a former occasion, that the frequency should be low, and that the currents forming the arc be large, in order to render the magnet more effective.

A form of such discharger with a magnet, which has been found convenient and adopted after some trials, in the conversion of direct currents particularly, is illustrated in *Fig.* 2. *N* and *S* are the pole pieces of a very strong magnet which is excited by a coil *C*. The pole pieces are slotted for adjustment and can be fastened in any position by screws s_1 s_1. The discharge rods d d_1 thinned down on the ends in order to allow a closer approach of the magnetic pole pieces, pass through the columns of brass b b_1 and are fastened in position by screws s_2 s_2. Springs r r_1 and collars c c_1 are slipped on the rods, the latter serving to set the points of the rods at a certain suitable distance by means of screws s_3 s_3, and the former to draw the points apart. When it is

desired to start the arc, one of the hard rubber handles h h_1 is tapped quickly with the hand, whereby the points of the rods are brought in contact, but are instantly separated by springs r r_1. Such an arrangement has been found to be often necessary, namely, in cases when the E. M. F. was not great enough to cause the discharge to break through the gap, and also when it was desirable to avoid short-circuiting of the generator by the metallic contact of the rods. The rapidity of the interruptions of the current with a magnet depends on the intensity of the magnetic field and on the potential difference at the ends of the arc. The interruptions are generally in such quick succession as to produce a

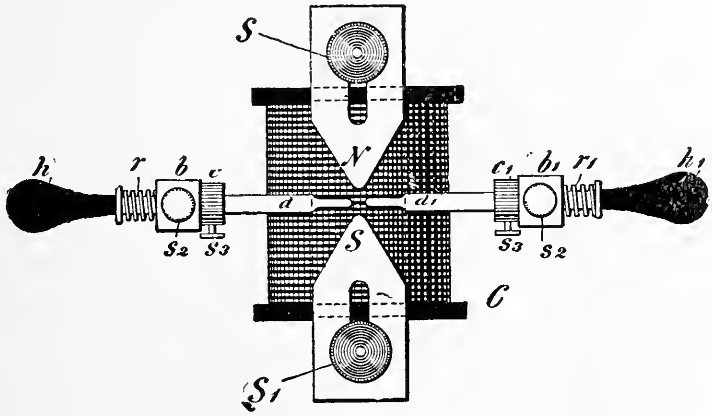


Fig. 2

FIG. 2.—Form of discharger with magnet used in the direct-current conversion.

musical sound. Years ago it was observed that when a powerful induction coil is discharged between the poles of a strong magnet, the discharge produced a loud noise not unlike a small pistol shot. It was vaguely stated that the spark was intensified by the presence of the magnetic field. It is now clear that the discharge current, flowing for some time, was interrupted a great number of times by the magnet, thus producing the sound. The phenomenon is especially marked when the field circuit of a large magnet or dynamo is broken in a powerful magnetic field.

When the current through the gap is comparatively large, it is of advantage to slip on the points of the dis-

charge rods pieces of very hard carbon and let the arc play between the carbon pieces. This preserves the rods, and besides has the advantage of keeping the air space hotter, as the heat is not conducted away as quickly through the carbons. The result is that a smaller E. M. F. in the arc gap is sufficient to maintain a succession of discharges.

Another form of discharger which may be employed with advantage in some cases is illustrated in *Fig. 3*. In this form the discharge rods $d\ d_1$ pass through perforations in a wooden box *B*, which is thickly coated with mica on the inside, as indicated by the heavy lines. The perforations are provided with mica tubes $m\ m_1$ of some thickness, which are preferably not in contact with the rods $d\ d_1$. The box has a cover *C*, which is a little larger than the box and descends on the outside of it. The spark gap is warmed by a small lamp *l* contained in the box. A plate *p* above the lamp allows the draught to pass only through the chimney *c* of the lamp, the air entering through holes *o o* in or near the bottom of the box and following the path indicated by the arrows. When the discharger is in operation the door of the box is closed so that the light of the arc is not visible outside. It is desirable to exclude the light as perfectly as possible, as it interferes with some experiments. This form of discharger is simple and very effective when properly manipulated. The air, being warmed to a certain temperature, has its insulating power impaired. It becomes dielectrically weak, as it were, and the consequence is that the arc can be established at much greater distance. The air should, of course, be sufficiently insulating to allow the discharge to pass through the gap *disruptively*. The arc formed under such conditions, when long, may be made extremely sensitive, and the weak draught through the lamp chimney *c* is quite sufficient to produce rapid interruptions. The adjustment is made by regulating the temperature and velocity of the draught. Instead of using a lamp, it answers the purpose to provide for a draught of warm air in other ways. A very simple way which has been practised is to inclose the arc in a long vertical tube with plates on the top and bottom for regulating the temperature and velocity

of the air current. Some provision had to be made for deadening the sound.

The air may be rendered dielectrically weak also by rarefaction. Dischargers of this kind have likewise been used by me in connection with the magnet. For this purpose a large tube is provided with heavy electrodes of carbon or metal, between which the discharge is made to pass, the tube being placed in a powerful magnetic field. The exhaustion of the tube is carried to a point at which the discharge breaks through easily, but the pressure should be more than seventy-five millimetres, at which the ordinary

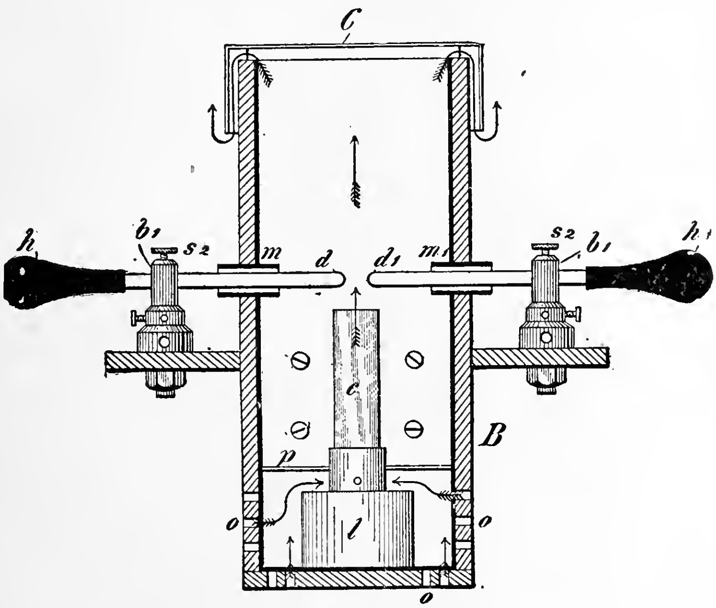


Fig. 3

FIG 3.—Discharger with hot-air draft.

thread discharge occurs. In another form of discharger, combining the features before mentioned, the discharge was made to pass between two adjustable magnetic pole pieces, the space between them being kept at an elevated temperature.

It should be remarked here that when interrupting devices of this or any other kind are used, and the currents are passed through the primary of a disruptive discharge coil, it is not, as a rule, of advantage to produce a number of interruptions of the current per second greater than the natural frequency of vibration of the dynamo supply circuit,

which is ordinarily small. It should also be pointed out here, that while the devices mentioned in connection with the disruptive discharge are advantageous under certain conditions, they may sometimes be a source of trouble, as they produce intermittences and other irregularities in the vibration which it would be very desirable to overcome.

There is, I reget to say, in this beautiful method of conversion, a defect, which fortunately is not vital, and which I have been gradually overcoming. I can best call attention to this defect and indicate a fruitful line of work by comparing the electrical process with its mechanical analogue. The process may be illustrated in this manner: Imagine a tank with a wide opening at the bottom, which is kept closed by spring pressure, but so that it snaps off *suddenly* when the liquid in the tank has reached a certain height. Let the fluid be supplied to the tank by means of a pipe feeding at a certain rate. When the critical height of the liquid is reached, the spring gives way and the bottom of the tank drops out. Instantly the liquid falls through the wide opening, and the spring, reasserting itself, closes the bottom again. The tank is now filled, and after a certain time interval the same process is repeated. But it is clear that if the pipe feeds the fluid quicker than the bottom outlet is capable of letting it pass through, the bottom will remain off and the tank will still overflow. If the rates of supply are exactly equal, then the bottom lid will remain partially open and no vibration of the same and of the liquid column will generally occur, though it might, if started by some means. But if the inlet pipe does not feed the fluid fast enough for the outlet, then there will always be vibration. Again, in such case, each time the bottom flaps up or down, the spring and the liquid column, if the pliability of the spring and the inertia of the moving parts are properly chosen, will perform independent vibrations. In this analogue the fluid may be likened to electricity or dielectric, and the pipe to the conductor through which electricity is supplied to the condenser. To make this analogy quite complete it is necessary to make the assumption that the bottom, each time it gives way, is knocked violently against

a non-elastic stop, this impact involving some loss of energy, and that, besides, some dissipation of energy results, due to frictional losses. In the preceding analogue the liquid is supposed to be under a steady pressure. If the pressure of the fluid be assumed to vary rhythmically, this may be taken as corresponding to the case of an alternating current. The process is then not so easily followed, but then action is the same in principle.

[*To be continued.*]

PRESENT DEVELOPMENT OF HEAVY ORDNANCE IN THE UNITED STATES.

By W. H. Jaques, Ordnance Engineer.

[*A lecture delivered before the Franklin Institute, January 6, 1893.*]

The lecturer was introduced by the Secretary of the Institute and spoke as follows:

Mr. Chairman and Members of the Institute:

A few days after the issue of the notice by your Institute that I would come here to-night for the purpose of telling you something about recent progress in the United States in the manufacture of heavy ordnance, I received a letter from a friend which I shall take the liberty of reading to you:

"It affords me pleasure to be the recipient of cards for a lecture to be delivered by you at the Franklin Institute on Friday, January 6, 1893, and I thank you for the opportunity you have so kindly afforded me to listen to your essay on the 'Recent Development of Heavy Ordnance in the United States.' I shall be there and shall look forward to hearing something new and interesting on that occasion."

In my response to him I wrote:

"Replying to your favor of the 24th, when you recall departmental and manufacturing reticence, you will perhaps not be surprised if you do not hear anything new," and this must be my excuse for doing little more than repeat

in a revised form my lecture delivered to the New York Naval Reserve Association last May.

As our good friend, Mr. Kirchhoff, has already made you familiar with the major part of it through the columns of his excellent journal, *The Iron Age*, I shall have to ask your indulgence to consider that publication as taking the place of the advance copies of papers usually distributed to their members by scientific societies.

As stated as a prelude to that lecture, in these days when the representatives of our press so readily familiarize themselves with the details of technical subjects, it is very difficult to describe operations, give results of tests, or suggestions as to future experiments without encroaching more or less upon information already given; for it must not be forgotten that in the splendid organizations of the press of this country there exist technical staffs whose members not only report the results of experiments that are made, but, as a consequence of the study and research which enables them to make the intelligent reports they give us, are also competent to make valuable suggestions to those who are engaged in developing the various arms.

In describing the construction of heavy ordnance I shall keep within a period of ten years, since, with the exception of increasing the size of the parts and decreasing their number, there has been no radical change from the recommendations of the Gun Foundry Board which were confirmed by the Senate Ordnance Committees; and, although all the leading nations have been studiously searching for, and experimenting with, new types, we find ourselves to-day employing for service guns those recommended by these committees.

The decrease of the number of parts was a natural sequence of the development of the means in the United States for the certain production of these increased integers. This practice has continued until we have reached the type advocated by Mr. Gledhill, in 1886, in which the few cylindrical or conical parts that are used to make up the gun are assembled, after taper machining, under great hydraulic pressure, either alone or in combination with screwing and proper shrinkage.

During this period no great change in the composition of steel for guns has been accepted, although alloys containing manganese, chrome, tungsten, copper, nickel, aluminum, etc., have been suggested and tried, with the view of securing increased hardness to resist the erosion, or a greater elastic strength to control the pressures that have accompanied the higher velocities.

Nitro-compound powders have been developed and successful results are reported where the highest service velocities have been obtained with half of the charges of brown powder previously employed. The enduring qualities of these so-called smokeless powders are doubted by many artillerists, but I have recently had the pleasure of receiving a visit from Mr. Alexander Anderson, who for many years was associated with Professor Abel, at the Royal Laboratory, Woolwich Arsenal, England, and who is credited with having perfected and patented the well-known smokeless powders whose methods of production are now controlled by the Chillworth Company. Of the stability of this new powder he assures me there is no doubt.

Referring further to what has been accomplished in Great Britain with the new powders, another English authority writes:

"In 1877, Capt. Andrew Noble, C.B., F.R.S., acting in conjunction with Sir Frederick Abel, F.R.S., carried out experiments to determine the action of gunpowder. These researches led to the construction by Elswick of six-inch and eight-inch guns, with which velocities up to 2,100 feet per second were obtained. And this important advance was followed everywhere by the use of the slow-burning powders in guns of increased length. With modern powder the velocities of the most powerful armor piercing guns may be taken at from 2,000 to 2,100 foot-seconds. But we are not at all at the end of progress, and as investigations in powder are carried on, even better results will probably be obtained.

With "amide" powder nearly 2,500 feet velocity has indeed already been obtained from a six-inch gun with moderate pressures, and a new explosive called "cordite,"

recommended by the Committee on Explosives, has given even better results than this."

With a charge of nineteen and one-half pounds of this powder a muzzle velocity of 2,669 feet has been obtained with the six-inch quick-firing gun.

"Of ballistite, and the host of other explosives now being introduced, we need not here speak, because they have not yet passed the experimental stage.

"Perhaps the most promising is cordite, resembling long pieces of thin black or gray cord. The climatic trials of cordite are, however, not yet complete. Many of the mixtures of this kind are very apt to deteriorate by keeping, and to become uncertain in action in hot climates, and experiments in this direction must always be very completely carried out before the final adoption of an explosive. One of the causes which has made gunpowder so successful an agent for the purposes of the artillerist, is that it is a mechanical mixture, not a definite chemical combination, and that it is practically impossible to detonate it."

Reports from France speak enthusiastically of the results that French chemists and artillerists have obtained.

Our own officials state that the macaroni form has been adopted and that repeated experiments have further demonstrated its stability and safety.

Duff Grant, in his lecture delivered before the United Service Club of New York, December 17, 1892, gave an interesting comparison of the qualities of the old and new powders. He is Secretary of the Smokeless Powder Company, of London, and as such presented the productions of his company in the most favorable light; but even he tells of the danger of most of the nitro types.

Longridge, in April, 1892, in his advocacy of a more powerful field gun than that in use in the British service, based his proposals on the use of Nobel powder, stating that although he possessed very limited information respecting cordite, he had reason to believe that there would not be any great difference in the results were cordite substituted for the Nobel powder. Yet in the same paper he thanks the "*new powders*" for the immense progress already realized

and expected in ballistic power, but calls attention to their increased pressures, which he thinks the wire system of construction* will be utilized to resist.

Speaking further of them, he says: "It is a common error to suppose that these powders are a new discovery: they have been known in substance for the last thirty or forty years. What is new, is the improvement in the means of controlling their rate of combustion, so as to regulate the development of the pressure and permit of their safe use in guns. It now remains to adapt the guns to the new powders, so as with safety to utilize their vastly superior force."

But even Longridge, with all his enthusiastic claim for the incontestable superiority of the new powder, calls attention to the danger to be guarded against from the very fact of its being a so much more powerful agent.

Many interesting and successful experiments have been made, each nation claiming for its own invention the greatest amount of usefulness and stability. Few military questions are discussed now with more fervor than that of the advantages and disadvantages of these nitro-explosives. Their advocates say: *My* powders can be used by anybody without fear; but they generally add: The greatest care, however, must be employed in their use. To which last statement their opponents point as indicating a well-known existence of danger that must not be overlooked.

In adhering to the built-up system of forged steel as the best type of gun construction, it is not with a feeling that some other type may not take its place and perhaps be more successful, but because we know all about it, what it will do, the strength of every part and how to insure it.

If anyone had assured us twenty years ago that cars would be speeding along rails at the rate of thirty miles an hour without horse or steam or cable power, simply by a force transmitted through wires; that we could talk over a wire for a distance of 1,000 miles with greater ease and distinctness than through the ordinary speaking tube; that

* Lantern view.

aluminum could be bought for fifty cents a pound; that colors could be photographed; that photograph-telegraphy would be accomplished; we would have received his statements with great incredulity and would have listened to such suggestions with even less faith, if it were possible, than we now receive the prediction of Lieutenant Totten in regard to the destruction of the world; or, if we could have accepted them, would have regarded our informant as possessing miraculous foresight.

Therefore, while I accept the built-up forged steel gun as the best because I know how it can be made a perfect machine, and because I can recommend its being put into service without fear of its doing more harm to its friends than to its enemies, I have no desire to discourage the enthusiastic supporters of other types, for they may succeed as others have done before them, and the built-up forged steel, high power, breech-loading gun may be as permanently superseded as iron has been supplanted and replaced by steel.

Instead of suggesting designs for revolutionizing the present accepted type, I will proceed with the details of its manufacture.

You are all familiar with the production of the pig in the blast furnace,* the parts, method of filling and blowing in, action and operation of the furnace and its accessories.

As the American furnaces have jumped to the front in the production of pig iron, it may be interesting to recall the dimensions of one of the largest. It was built in 1885–86: has a total height of 80 feet; diameter of hearth, 11 feet; diameter of bosh, 23 feet; the bell is 12 feet in diameter, and the stock line 16 feet; the cubical capacity is 19,800 feet; it has seven tuyeres of 6-inch diameter. The blast was used at a temperature of 1,200°, entering the tuyeres at a pressure of from nine to ten pounds. The highest monthly output was 12,706 gross tons, or an average of nearly 410 tons per day.

In reply to inquiries concerning the data just mentioned,

* Lantern view.

Messrs. Swank and Birkinbine kindly sent me the following letters:

THE AMERICAN IRON AND STEEL ASSOCIATION.

PHILADELPHIA, January 3, 1893.

Lieut. W. H. Jaques, South Bethlehem, Pa.

DEAR MR. JAQUES—I have received your letter of yesterday. The furnace you speak of, by a singular coincidence, is identical in height, diameter of hearth and diameter of bosh, with one of the Edgar Thomson furnaces which performed such good work under Mr. Gayley's management, in 1886 and 1887, and again in 1888, 1889 and 1890, that Mr. Gayley was induced to write up its record for the meeting of the British Iron and Steel Institute at New York in October, 1890. * * * Very truly yours,

JAMES M. SWANK.

THE AMERICAN INSTITUTE OF MINING ENGINEERS.

PHILADELPHIA, January 3, 1893.

Lieut. W. H. Jaques, South Bethlehem, Pa.

MY DEAR SIR—I have your favor of the 3d, giving me the dimensions of what I take to be one of the Edgar Thomson furnaces, and asking if I have anything larger than this on my record. I do not think there is now anything larger in the United States, unless it be one of the other furnaces of the Edgar Thomson Works, some of which are ninety feet high. The tendency has been rather to keep within moderate limits, and some of the very large furnaces have been lined to smaller diameters than their original construction planned.

Between 1865 and 1873 there was a tendency in Great Britain to construct very large furnaces, but I understand most of these have been reduced in size. Below I give you the dimensions of some:

Feet High.	*Feet Bosh.*	*Feet Capacity.*
85	25	26,000
95½	22	25,940
95½	23	28,800
80	25	25,000
80	24	24,613
90	30	41,149
85	27	32,000
85	28	30,000
95½	24	28,950

Fully twenty-five furnaces were built of these large dimensions, but when it comes to production in comparison to the cubical contents, our English cousins are "not in it" in comparison with us. Trusting this may be of service, I am, Yours truly,

JOHN BIRKINBINE.

Although Krupp uses the crucible process almost exclusively and Russia employs it largely, most of the gun steel,

and all of it in the United States, is made by the open hearth process, the metal being melted in *open hearth* instead of in closed pots or crucibles. Steel made by other processes than the open hearth and crucible has shown physical characteristics equal to and in some cases more remarkable than those which fulfil the present requirements; but when such steels were used for gun construction it was found that they were not adapted to the purpose.

There are many forms of the open hearth furnace, differing in arrangement of regenerators, valves, shape of hearth and slope of roof, but their general construction will be understood from the accompanying view of a Siemens regenerative gas furnace.*

After the sole or bottom of refractory sand has been made and the hearth has been brought to a full heat, the raw materials, iron ore, pig iron, wrought-iron blooms, and steel scrap are put in through the doorways, generally in a solid state. As soon as the whole charge has been fully melted a series of tests is begun, which usually consists in taking samples in small ladles and casting them into small test ingots. These are cooled and broken and by the changing indication of the fracture and carbon determinations, as the process advances, the exact condition of the bath is obtained.

The reduction of the carbon is continued until it stands at the required percentage, when the bath is recarburized, by the introduction of a quantity of preheated spiegel or ferro-manganese, after which the metal is stirred and the contents of the furnace tapped into a ladle.*

The ladle is then transferred by rail to the fluid compression plant* where the steel is compressed or run into the moulds for which the metal has been intended.

The sizes of the ladles are governed by the capacity of the furnaces and the class of work for which the steel is to be used. Of heavy iron construction, they are lined with a refractory mixture and pierced in two places in the bottom for the insertion of fire-brick nozzles, through which the metal runs into the moulds. Into these nozzles clay-plum-

---

* Lantern view.

bago stoppers are fitted and attached to heavy rods which extend upward and out over the side of the ladle to the levers or other attachments provided for lifting and controlling them. The device shown in the view* is a simple and effective one.

The moulds are of steel, iron, brick, or sand, and are of dimensions and shapes suited to the purpose for which the ingot or casting is to be used.

Bethlehem has four open-hearth melting furnaces, of the respective capacities of fifteen, thirteen, and two forty tons.

The Whitworth system of fluid compression consists in compressing the liquid metal in a mould immediately after pouring. The moulds are tapered cylinders made of steel and lined with refractory material. As soon as the mould is filled it is moved under the fixed head of the press* and the pressure applied.

As soon as the ingot has cooled and contracted sufficiently, the mould is removed by the crane*, and the ingot is lifted out of the casting-pit and taken to the heating furnace to be raised to the forging temperature.

These heating furnaces are of the general Siemens regenerative type, with large doors in front and rear, operated by hydraulic power and with spacious heating chambers to admit the largest work. When the ingot or block is raised to the needful temperature it is removed from the furnace and put under the hydraulic forging press* to be shaped. This press consists of a massive head and bottom secured by four forged steel columns held together by nuts. The head carries the hydraulic cylinder and ram with which the work is done upon the piece to be forged as it rests upon the anvil. The piece upon the anvil in the view* before you is a hollow forging, the hole in the block having been bored or punched previous to putting it into the heating furnace. The press is fitted with cranes and other mechanical contrivances for the handling of the forging while it is being shaped.

The operations of drawing out a tube and enlarging a

---

* Lantern view.

hoop by this method are represented in the following sketches.* Into the heated hollow ingot a steel mandrel is inserted and both are placed between suitable dies fitted to the ram and anvil. As repeated pressures are given, the ingot and mandrel are turned round into fresh positions, and, as the metal cannot flow except in the direction of the length, the tube is reduced to the required diameter and drawn out to the requisite length.

This view* represents a hollow cylinder weighing 28,250 pounds; 44 inches exterior diameter; 60 inches long, with a hole $14\frac{1}{2}$ inches diameter.

It is represented here* before forging and was drawn down in one heat to a hollow cylinder 160 inches long; 30 inches exterior diameter, with the hole reduced to 14 inches, as shown here.*

These two figures* represent the operation of drawing out a solid ingot (which before forging was 92 inches long and 42 inches diameter) in one heat to the shape represented here.* In this heat half of it has been drawn into a forging twenty inches in diameter; if the remaining portion is to be reduced to the same size, that not reduced will be re-heated and drawn down in the same manner.

The two figures* on the left represent the result of the operation of enlarging a hoop, which is shown in the upper figure* before forging, and in the lower* with the shape and dimensions which have been given to it during the extension.

This enlargement is produced by supporting the mandrel at both ends, leaving the hoop without any bottom support during the forging, which operation gradually increases the diameter and reduces the thickness of the walls without materially increasing its length.

The forgings being finished, they are then taken to the machine shop, where, in lathes illustrated by the following views,* they are rough-turned and bored to their rough dimensions.

The forging is centred between the adjustable head-

---

* Lantern view.

stock and the chuck, which is fitted with steel adjustable jaws. As the forging is turned in the lathe the tools fitted to the adjustable tool-holders in their carriages machine it to the required dimensions, the tools being fed and the carriages traversed by suitable power and gearing. The number of tools employed (four in the lathe* before you) depends upon the power of the machine and the methods of the manufacturer.

In boring,* one end of the forging is attached to the chuck and centred in rests, and as the forging revolves, the tool at the end of the boring bar is fed as required.

When rough-bored and turned, the forging is taken to the tempering furnace,* raised to the desired temperature, dipped into that liquid which is considered best to secure the requisite temper, and returned to the machine shop for the taking out of the specimens, the physical tests and appearance of which are to govern the acceptance or rejection of the piece they represent.

Authorities differ as to the value of oil hardening, but universally agree as to the benefits of annealing. Both are necessary to secure a reliable, uniform product. All gun forgings should be carefully annealed in order to bring to a normal condition any molecules or particles which may have been disturbed by unequal cooling or working. Any form of heating furnace can be adapted for this operation, but those especially designed for the use and control of gas are to be preferred.

The specimens used by the Navy Department are of the type and dimensions* here represented, while those for the army are the ones* that you now see before you.

The forgings that go to make up the gun, having been accepted by the inspectors, are sent to the gun factory for assembling and finishing.

The Bethlehem Company has contracted to furnish the War Department with 100 high-power breech-loading guns of eight-inch, ten-inch and twelve-inch calibre, finished complete, and its gun factory is now being rapidly equipped with the special machinery needed for their fabrication.

---

* Lantern view.

The interesting view* now before you represents the interior of the principal gun shop of the Washington gun factory. The machines are arranged across the shop and are served by two travelling cranes of twenty-five and 100-ton capacity. The turning and boring lathes* employed for finishing are similar in construction to those used in the rough work, but are not required to be so powerful. In the final machine finishing fewer tools are used.

In the first two machines of the view before you the operation of boring is being performed, the bit being attached to a long, strong bar, which is fed into the revolving tube or hoop.

Peculiarly-shaped bits,* called "packed-bits" and "hog-bits," are employed for this work.

The next operation, after the parts are reduced to their finished sizes, is the assemblage. In this view* we have the tube and jacket represented before assemblage, while the lower figure* represents the parts as assembled.

The operation of jacketing a gun is shown in the two following views.* The tube is secured in a vertical position in a large pit, and the jacket, raised to its shrinkage temperature in a hot-air furnace, is lifted from the furnace by the travelling crane and lowered to its proper place upon its tube. Water circulating through the interior of the tube and sprayed upon the lower end of the jacket governs the cooling to secure the proper shrinkage.

The view* before you now is a very interesting one, showing jackets for the four, five, six, eight, ten and twelve-inch navy guns, ready for insertion in the heating furnace for shrinkage upon their respective tubes.

The hoops are shrunk on in a similar way, although much of this work in some factories is done in the lathe, the gun being then in a horizontal position.

The effective power of shrinkage is well illustrated in the accompanying view, *Fig. 1*, a reproduction of an experiment made many years ago at Sir Joseph Whitworth's works in England, to show its effect and value.

---

* Lantern view.

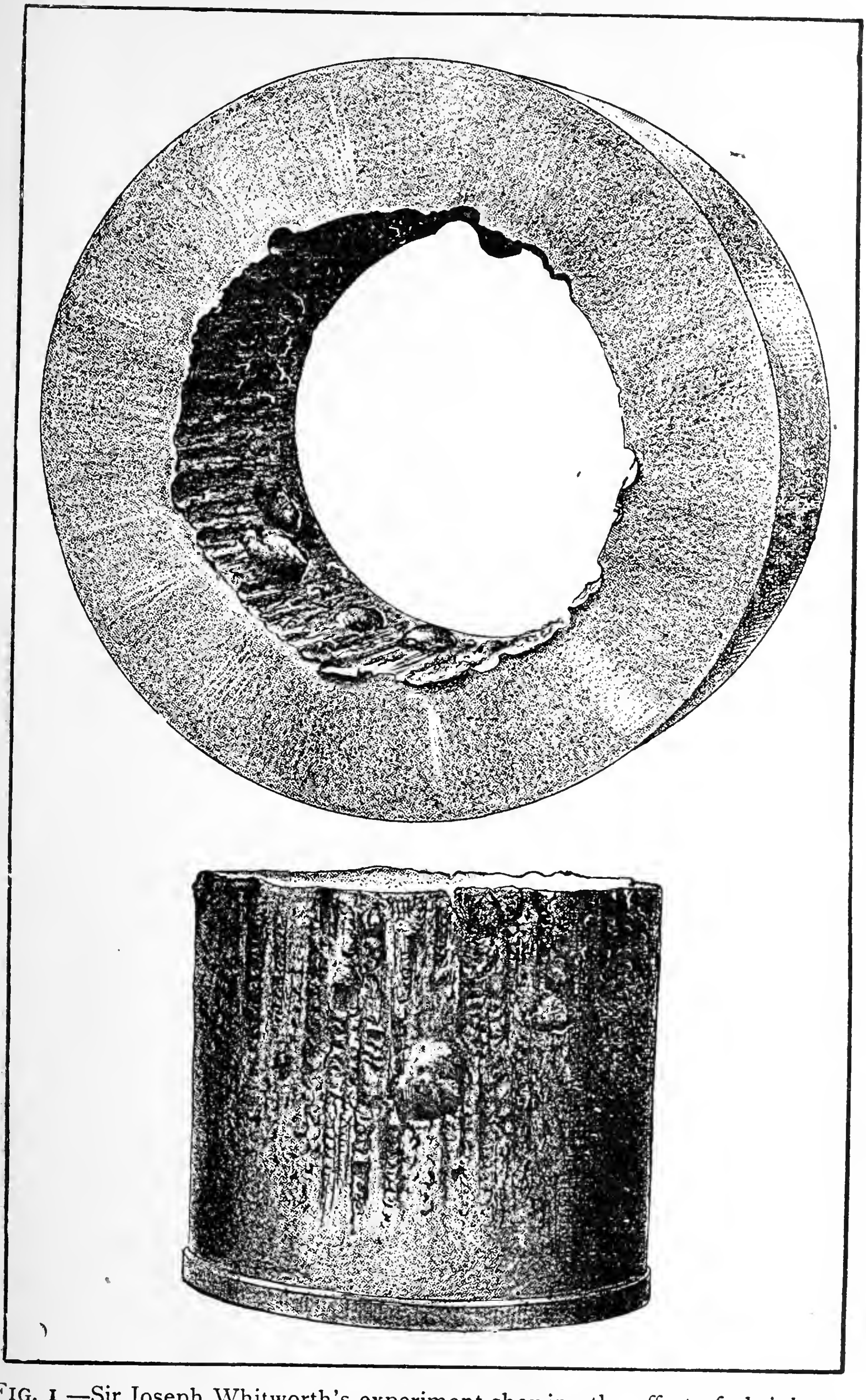


FIG. 1.—Sir Joseph Whitworth's experiment showing the effect of shrinkage.

A ring of mild, fluid-compressed steel, 30 inches exterior diameter and 30 inches long, was heated and shrunk on to a plug 18 inches diameter and 16 inches long, having a 6-inch hole bored through its centre, the plug being turned up larger than the diameter of the ring by the proper shrinkage allowance. When cold, the plug was forced out by dydraulic pressure and it was found that it required a force of 3,000 tons to separate the two pieces.

Directly connected with the subject of shrinkage is the problem of the value of *internal stresses.*

Rodman is credited by Kalakoutsky with the explanation of their cause and importance and by Birnie for the exposition of the principle of initial tension in hooped guns, and to giving to the several layers of hoops such a shrinkage as would cause each to offer its full strength in resisting the action of an interior pressure calculated to rupture the gun. But Rodman applied them only in the foundry. Both, however agree that we are indebted to Lame for the *origin* of the principles. Further, we owe many thanks to the late General Kalakoutsky, of the Russian Artillery, and to Captain Crozier, of the United States Ordnance Department, for their independent researches, which determined a numerical value for these stresses and pointed out how they could be converted from injurious into beneficial quantities.

When pressure is applied to a hollow cylinder, either externally or internally, the interior layers into which its walls may be conceived to be divided are subjected to a new series of stresses, which combine with the former in such a manner that at every point of the thickness of the cylinder they have common resultants.

As already stated, these have all been given numerical values which are employed in all shrinkage work at the present time, their theoretical values having been frequently verified by a very large number of experiments both in Europe and the United States. These numerical values, evolved from the natural stresses, are employed to determine the magnitude of the stresses of built-up cylinders,

stresses which are mechanically put into these cylinders, when formed of materials of such thicknesses and condition as may be assumed to be practically free from initial stresses, or combined with the initial stresses (if they exist in any of the parts), or with the stresses which may arise in the course of manufacture. Useful stresses are developed and construction regulated accordingly.

General Kalakoutsky devoted nearly twenty years of his life, from 1871 to 1889, the date of his death, to the consideration of these important questions, and to the determination of the law of the distribution of these stresses under the conditions of manufacture. He defined internal stresses as those which exist within the mass of any body when it appears to be in a state of repose or not under the influence of external forces.

The formulæ and tables followed in the regulation and preparation of the required shrinkages are the result of long years of research, study and experiment, and I know of no treatise on the subject which defines so simply and definitely the injuries and benefits of internal stresses as a work published in 1888, entitled *Investigations into the Internal Stresses in Cast Iron and Steel*, written by the late General Nicholas Kalakoutsky, of the Imperial Russian Artillery.

I had the pleasure of knowing and seeing much of him during the last part of his life, and enjoyed greatly the opportunities which my intercourse with him secured for me; I had the further satisfaction and pleasure of bringing Kalakoutsky and Crozier to a more intimate appreciation and knowlege of what each was accomplishing.

The reports of the official investigations to determine for the army the class and quality of material and the basis for shrinkages to be employed in the construction of steel built-up guns are very attractively summarized in Birnie's "Gun-making in the United States," published in the *Journal of the Military Service Institution*, in 1891. In it he gives diagrams showing the elasticity of steel, sections of parts prepared for assemblage, their position at various stages of

assemblage, the various compressions, and the use and modifications of Clavarino's formulæ.

Birnie found in his hoop shrinkage experiments that the degree of accuracy obtained was ninety-eight per cent. of the anticipated mathematical results, which, together with other results he acquired, fully justifies the claim that the production of the proper degree of tensions in a built-up gun is a certain process.

A long list of experiments has not only supplied us with a vast amount of valuable mechanical and metallurgical data, but has given us additional assurance of the strength and endurance of the built-up forged steel gun, as far as the material and construction are concerned.

There is another question, however, in connection with gun construction, which has not yet been satisfactorily solved, a solution of which may not be so easily attained; that is, how to prevent the erosion of the bore by powder products. This wearing of the barrel is at the present time a cause of the greatest anxiety to ordnance engineers and gun makers. Its disastrous effects* in ordnance where such enormous powder charges are employed have no doubt greatly influenced some artillerists against the largest calibres, whose racking and smashing powers must be employed to destroy the heaviest armor.

If we do not change the propelling agent I believe we must look to the amount of work put upon the metal and its treatment rather than to the chemistry alone of the metal for the determining agents that will prevent or reduce the amount of erosion; and that the solution of the problem will be found in the mechanical field. This difficulty will probably be best surmounted by carbonizing the bore, which should be highly polished or hardened by mechanical mandrelling, in order to secure the smoothness needed to prevent scoring by powder products. The employment, therefore, of any alloy or of any mechanical work that will aid in securing this highly hardened smoothness, without reducing the requisite elastic strength, will greatly

---

* Lantern view.

assist the solution of this difficult problem. These results cannot be obtained, however, by any sacrifice of attention to the chemistry of gun steel.

If erosion is mainly due to the chemical action of the powder gases and deposits that some powders leave the powder maker, by changing the mechanical or chemical composition of his products or substituting some other propelling agent, may pass the mechanic in his search for the means of rendering his gun barrel impervious to the destructive action of powder just as the manufacturers of slow-burning powder outstripped the designers of accelerating guns in securing high velocities.

If we accept the new powders we may have to sacrifice the excellent ballistic results that the erosive powders have given, but if the mechanic succeeds, any kind of powder can probably be used.

If erosion is due to high pressures and temperatures the use of the stronger powders would increase erosion in the proposed short guns; but if it is due to the mechanical work of the non-gaseous (liquid and solid) residue, these new powders, if they can be made reliable, will be a boon.

The shrinkage tables at present used by the two gun factories in their fabrication of built-up guns were, I believe, prepared by Lieutenant Commander Dayton and Professor Alger, of the Navy, and by Captains Birnie and Crozier, of the Army.

After the final finish-turning* and boring* has been accomplished the gun is chambered,* the chamber being of a diameter greater than that of the bore, and the gun is put into the rifling machine* to be rifled. The rifling head is fitted as here* represented, and the rifling is effected usually during the withdrawal of the head by the bar to which it is attached. The number of cutters on the rifling head varies in different machines and the pitch of the rifling is governed by the guide bar as represented in this view* or by gearing.

The threading* and slotting* are done by what is usually

---

* Lantern view.

called a threading and slotting machine,* which carries a tool in an adjustable holder that screws the thread or is employed as a slotter to remove those segments of the thread which allow the entrance of the interrupted screw of the breech plug, the gun being carefully centred in centring rests.

This view* shows on a larger scale the operation of cutting the slot ways.

The breech plug, with its mushroom or other gas check, and the various devices for opening, closing, latching and firing, are then fitted, the gun is sighted and carefully examined, and we have the finished gun.*

The present view* represents a twelve-inch navy gun fitted to a proof carriage, showing the method of securing it to the slides, its breech mechanism open and a telescopic ram for loading attached to the carriage.

As there are still a few believers in muzzle loading it may be well to recall the advantages of breech loading: It permits the projectile to be of the greatest possible diameter, secures accuracy of fit, and affords the best means for the application of the expanding material to take the rifling. Any sparks remaining in the bore can be easily and surely removed, thereby preventing a not unusual source of danger. Any injury to the vent can be readily repaired in the movable breech-piece. The gun can be more rapidly fired, and the fouling of the bore does not interfere with the loading. There is no danger of double shotting. The bore can be more readily inspected and any weakness more easily discovered. And, above all, breech-loading permits increased length of guns for use on board ship, and provides greater protection for the gunners.

[*To be continued.*]

---

* Lantern view.

THE SPECIFIC HEATS OF THE METALS.

By Jos. W. Richards, Ph.D.,
Instructor in Metallurgy, etc., in Lehigh University.

[*A lecture delivered before the Franklin Institute, January 30, 1893.*]

The lecturer was introduced by the Secretary of the Institute and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

For the purpose of showing clearly the field to be covered, I will refer at once to five heads under which the subject will be considered:

(1) Definitions. The range of the subject.

(2) Methods.

(3) Historical Treatment. The investigators; work done by each.

(4) Discussion of the results. Tables, diagrams, formulæ.

(5) Theoretical Treatment. Discussion from the chemical and mechanical standpoints.

I.

The specific heat of a body is the ratio between the amount of heat necessary to increase its temperature 1°, and the amount necessary to increase the temperature of an equal weight of water 1°.

Being a *ratio*, it is of course independent of the weights of the substance and water taken, or of the kind of thermometric scale employed, but in order to introduce regularity into these comparisons the weights taken are a kilogramme or a pound, and the degree either Centigrade or Fahrenheit. Throughout this lecture I shall use the metric unit of weight and the Centigrade scale.

Since the observations on so many substances are to be compared with water as a standard, it will be well to

examine our standard carefully, to see if it is invariable. We find that *pure* water is absolutely the same substance at all times, so that no variation can arise from there being two kinds of water; but, examination reveals the fact that the amount of heat required to raise the temperature of a kilo of water 1° is a different amount at different temperatures. For instance, it takes more heat to heat a kilo of water from 90° to 91° than from 1° to 2°. Scientists have investigated this matter for fifty years, and it is only quite recently that reliable figures have been obtained showing just to what extent, quantitatively, the specific heat of water varies with the temperature. The French scientist, Regnault, had found a gradual increase from the freezing point up, and for this reason the water unit was chosen as the amount of heat required to raise a kilo of water from 0° to 1°; but since these observations of Regnault have been proven incorrect, the general conclusion now is that the water unit should be considered at from 15° to 16°, at which point the specific heat of water appears to reach a minimum value.

I have just explained how the specific heat of water varies with the temperature at which it is taken. This is also true of all other bodies, so that a complete investigation of the specific heat of any substance would mean the determination of that property at all attainable temperatures, from the lowest to the highest. In the course of such an investigation the substance would in many cases pass from solid to liquid and then to gas, and it would be found to possess different specific heats in these different states. Furthermore, in passing from solid to liquid, or from liquid to gas, it would be observed that a large amount of heat is absorbed without any increase of temperature at all. At these points we say that heat is rendered latent in the body. The complete calorific investigation of a body should therefore include the fixing of the temperatures at which such sudden absorptions of heat occur, and the amounts of heat rendered latent.

A new name has thus attached itself to this branch of experimental physics; we now speak of undertaking the "calorific investigation of a substance" in place of the mere

determination of its specific heat at ordinary temperatures.

While this subject is properly a branch of physics, we shall see more clearly further on that it treads very close to the foundation ground of chemistry, throwing a side light on many of the conceptions of that science, and tending in many ways to give us chemical theories on a purely mechanical basis.

II.

Referring to the experimental methods employed in these investigations, we may class them under two heads:

(1) The method of cooling.

(2) Calorimetric methods.

The first method may be briefly described as follows: The substance is made hot, and then placed in a close vessel kept at a constant temperature by a stream of water, and the rate at which it cools is carefully observed. A delicate thermometer embedded in the substance is read every five or ten seconds and the curve of cooling is carefully plotted. Since the conditions are such that the amount of heat radiated per second depends only on the temperature of the substance, it follows that the rate at which it will cool will depend directly on the amount of heat stored up in the body, or upon its calorific capacity. Thus, different substances can be investigated and compared, but it will be readily seen that the method gives only comparative results, and in order to get absolute values we must take some one substance whose specific heat has been otherwise determined as a standard, and then the values for the other substances can be calculated.

This method was first used by J. T. Mayer, in 1808, and afterwards greatly improved by Dulong and Petit, but the results obtained by it are not considered as accurate as those given by some other methods, and it is not now used to any extent. The complicated formulæ for cooling, which must be used, and the great care required to obtain good results have also helped to bring the method into disuse.

Under the second head, calorimetric methods, we include all those methods in which the heat capacity of a body is

directly measured. This may be accomplished in three ways:

(1) The method of mixtures.

(2) The ice calorimeter.

(3) The steam calorimeter.

The method of mixtures consists simply in heating up the substance to an accurately-determined temperature, and then immersing it suddenly in a known weight of water, or of any fluid whose specific heat is accurately known. From the temperature of the mixture, and the known specific heat of the liquid, the unknown specific heat of the substance under investigation, or rather the amount of heat given out by it in falling from the high temperature to the temperature of the mixture, becomes known. Of course, in determining the true temperature of the mixture it is necessary to make corrections for heat absorbed by the vessel in which the mixture takes place, etc., but this line would lead to a discussion of calorimetric methods which would be outside the scope of this lecture. But, aside from this difficulty, this method has other defects. One of these is the difficulty of accurately determining the temperature of the substance as it was dropped into the calorimeter. Even supposing that its temperature while in the air bath or furnace is accurately determined (a difficult matter for high temperatures) there is a certain fall in temperature during the transfer into the calorimeter, an amount which increases very rapidly with high temperatures. Another defect sometimes mentioned is loss of heat by vaporization of the water, but this is so small as to be in most cases negligible. The most serious of these defects, the first, has been remedied by the use of the "double method of mixtures," which consists in using two calorimeters and a platinum ball along with the substance being investigated. If the substance and the platinum ball are placed in the furnace together, then removed together and dropped simultaneously into the two calorimeters, the amounts of heat given out by each in cooling from the same temperature can be measured, for it can fairly be assumed that the platinum ball is at exactly the same temperature as the other substance at the

moment of immersion. But the specific heat of platinum has been investigated with the greatest care, and so from the amount of heat it has given out to the calorimeter we can calculate its temperature at the moment of immersion. In this way the most serious defect of the method of mixtures has been overcome, especially when working at high temperatures. Your lecturer has done considerable work by this double method, with very satisfactory results.

The ice calorimeter measures the heat given out by the substance in cooling to zero, by the weight of ice which it melts. Knowing just how much heat is absorbed by one gramme of ice in becoming water, it is necessary only to weigh the amount of water formed to get the heat given up. This calorimeter was first devised and used by Lavoisier and Laplace, and has been greatly improved by Bunsen. As a measurer of heat, its principal defect was that all the water produced could not be collected and weighed. Bunsen's improvements largely overcame this error. The other defects incident to its use were principally the loss of heat during transfer to the calorimeter, which can be overcome by the "double method" already explained. All determinations made in this calorimeter depend on the value of the latent heat of water, which is, however, known to a high degree of accuracy.

The steam calorimeter measures the amount of heat absorbed by a body in being heated up to 100°, by the amount of steam which it condenses in doing so. For this purpose, the substance at an accurately known temperature is suddenly plunged into a current of dry steam. The weight of water finally collecting on it is determined, and the heat absorbed by the body is the product of this into the latent heat of steam. Like the ice calorimeter, all determinations made in this way depend on this constant, the latent heat. More serious errors, however, are caused by the condensed water falling off the body, and by some of it being carried away mechanically by the steam. Also, since the latent heat of steam is very large, a small error in weighing the water condensed will make a large error in the result. No very exact figures can be expected from this method of investigation.

Before closing this description of methods, I might here remark that the latent heat of fusion, a very interesting phenomenon when speaking of the metals, can be determined in several ways. Assuming the melting point known, we can calculate from the observed variation of the specific heat in the molten state, how much heat the *molten* substance would contain at the melting point; we can in a similar way calculate how much heat the *solid* metal contains at that temperature; the difference between these two quantities will be the latent heat of fusion. Or, we may determine the first quantity directly, by taking a large quantity of molten metal and letting it cool gradually to the setting point. When part is already set, the part which is still fluid, and whose temperature is exactly the melting point, is poured out directly into a calorimeter, and the amount of heat in it is thus measured directly. The second quantity may also be determined directly, by taking a bath of molten metal, letting part set, and then plunging a little spiral of wire of the same metal into the still-fluid part. The heating up of the wire chills a certain quantity of metal into the solid state, at this temperature, and the little lump thus formed is dropped into a calorimeter. Or, the latent heat of fusion can be determined by the method of cooling; for the temperature of the metal remains constant, while the metal is setting, and from the time which it takes to set, compared with the rate at which the liquid and solid metal cools before and after the setting, the amount of heat evolved during setting can be computed. For this, however, we need to know the value of the specific heat of the metal somewhere in the neighborhood of its setting point.

III.

Historically considered, we may begin by saying that about 1750 it was universally supposed that there was little or no difference in the heat capacity of different kinds of substances, and it was further supposed that solids were converted into liquids by the addition of an insignificant amount of heat when they had once been raised to the melting point.

Dr. Black, of Edinburgh, was the first to announce correct ideas on these subjects. In his chemical lectures at Glasgow, between 1760 and 1765, he pointed out the great differences in the heat capacities of different substances, and made experiments in his lectures demonstrating the great amount of heat absorbed during the fusion of ice and the vaporization of water. He determined the latent heat of water to be 140° F. units, equal to 77°·8 C. units. A very able assistant of his, Dr. Irvine, made further investigations between 1765 and 1770, and determined the latent heat of fusion of tin, which he called 500°. By this he meant that the heat given out by tin in setting would be sufficient to raise the temperature of 500 times its weight of solid tin 1°; or an equal weight of solid tin 500°. These being Fahrenheit degrees would be equal to 277°·7 C. These we might call tin units, and to convert them into the ordinary water units we should have to divide them by the ratio of the specific heat of water to the specific heat of solid tin at its melting point. The figure thus reached is not far from that obtained by later observers.

Dr. Crawford was another colleague of Dr. Black, and published in his *Treatise on Heat* the results of many experiments on specific heats. It was said of him, thirty years later: "To this ingenious experimenter we owe some of the most remarkable facts respecting specific heat yet known." He investigated the specific heats of antimony, copper, iron, lead, mercury, tin and zinc.

Dr. Black called this newly investigated property of bodies "*capacity for heat*," but before the publication of his and his colleague's results, which was delayed by Dr. Black's great modesty, Professor Wilcke, of Stockholm, who had been working out similar ideas, published the results of some experiments and attached the name "*specific heat*" to this property. Professor Wilcke worked by the method of mixtures, and published values for antimony, bismuth, copper, iron, lead, silver, tin and zinc.

Dr. Kirwan, in England, made similar experiments, to obtain values for the specific heats of antimony, gold, iron, lead, mercury and tin.

Lavoisier and Laplace made experiments with their ice calorimeter. The only one of the metals which they seem to have investigated was mercury. We owe to Lavoisier the expression "*latent heat of fusion*," and we find in his writings a wonderfully clear conception of what specific heat really includes, how it increases with temperature and to a different amount in different substances. So clear were his views that an enthusiastic Frenchman exclaimed, in 1886: "All work on specific heats since his time has been done on the lines laid down by Lavoisier."

J. T. Mayer, Leslie and Dalton worked by the method of cooling, but only the latter gives results for the metals, and these appear to be very rough approximations. The method was afterwards greatly improved by Dulong and Petit. Count Rumford and Avogadro can also be included in the list of experimenters in this line, but their results, especially those of Avogadro, were little trustworthy.

Dr. Wm. Irvine, son of Dr. Black's one-time assistant, repeated and extended some of his father's experiments. He determined the latent heat of fusion of bismuth, lead, tin and zinc.

Rudberg, in 1830, determined the latent heat of fusion of lead and tin by the method of cooling.

Erman made similar experiments in 1830, but the discordance of his results shows that his apparatus was not properly constructed or managed.

F. E. Neuman determined in 1831 the specific heats of antimony, bismuth and zinc by the method of cooling. De la Rive and Marcet investigated cadmium, cobalt and molybdenum, by the same method.

Dulong and Petit were the first investigators to make any systematic study of the variation of specific heat with the temperature. They determined the specific heat of antimony, copper, iron, mercury, platinum, silver and zinc, at various temperatures up to 350° C. Their method was that of mixtures. They also determined the specific heats of antimony, bismuth, copper, gold, iron, lead, platinum, silver, tin and zinc at ordinary temperatures by the method of cooling. These scientists were the first to remark that

the specific heats of the elements are inversely proportional to their atomic weights; a law which while not rigidly exact, yet is so nearly true that the slight deviations from it may fairly be ascribed to other causes yet to be investigated. In fact, it will be seen further on, in discussing the theory of specific heat, that this law may be directly deduced from the modern mechanical theory of heat.

Bède in 1855, Byström in 1860, and Naccari in 1877, have made series of experiments in exactly the same manner as Dulong and Petit's first set by the method of mixtures, at temperatures between 100° and 300°. Bède examined antimony, bismuth, copper, iron, lead, tin and zinc; Byström, iron, platinum and siver; Naccari, aluminum, antimony, cadmium, copper, iron, lead, nickel, silver and zinc.

In 1836, Pouillet made a very careful study of platinum, using an air thermometer for recording temperatures and extending his determinations up to 1,200° C. He worked with great care, and his results would have been excellent had it not been that a defect in his air thermometer introduced an error of 30° or 40° in his determinations of very high temperatures, and thereby vitiated his results.

A classical set of experiments was made by Regnault by the method of mixtures. Commencing with 1840, he worked for several years in this field, giving us values which are usually regarded as standards. However, whenever he used metals not quite pure for his experiments, he gave figures which have since been revised. He used a steam bath for his upper temperature, so that his figures are really the mean specific heats between 10° or 15° and 98° or 99°, or the true specific heats in the neighborhood of 55° to 60°. He investigated twenty-seven of the metals, as follows: Aluminum, antimony, bismuth, cadmium, cobalt, copper, gold, iron, iridium, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, osmium, palladium, platinum, potassium, rhodium, silver, sodium, thallium, tin, tungsten and zinc.

Dr. Kopp was a laborious investigator of specific heats. He determined those of many metals and of a host of chemical compounds. He used the method of mixtures, but he

seems to have worked with unusually small weights of the substances, and from this cause or some others inherent in his apparatus his results on the same substance often varied among themselves five per cent., and occasionally even ten per cent. In all such cases he figures up the average value of all his determinations. Regnault's results for one substance seldom varied over one per cent. from each other, so that wherever Kopp's values vary from Regnault's, the latter's deserve the preference. Kopp obtained the mean specific heats between 10° or 20° and 60° or 70°, or the true specific heat at about 35° to 40°. He investigated aluminum, antimony, bismuth, chromium, copper, cadmium, lead, magnesium, platinum, silver, tin and zinc.

Professor Bunsen used his modification of the ice calorimeter for determining the mean specific heats of antimony, calcium, cadmium, indium, ruthenium, silver, tin and zinc, between 0° and 100°, or the true specific heats at about 50° to 55°.

Professor Mallet determined the specific heat of chemically pure aluminum (used in investigating its atomic weight) between 0° and 100° with Bunsen's ice calorimeter.

Person used Regnault's apparatus and the method of mixtures to determine the specific heats of bismuth, cadmium, lead, tin and zinc in the solid and liquid states, from which data he calculated their latent heat of fusion. He also determined the latent heat of fusion of cadmium, silver and mercury by the method of cooling.

Dr. W. F. Hillebrand, in 1876, determined the specific heats of cerium, lanthanum and didymium by the Bunsen ice calorimeter.

T. S. Humpidge determined the specific heat of beryllium in 1885.

L. Pebal and H. Jahn investigated antimony between — 76° and + 33°.

Zimmerman and Bluncke both determined the specific heat of uranium.

Nilson and Pettersson investigated germanium and titanium.

Milthaler investigated mercury at different temperatures and derived a formula for the variation of its specific heat with the temperature. Naccari went over the same ground for temperatures between 0° and 250°.

Kunt and Warburg investigated the specific heat of mercury vapor. E. Reynolds determined the specific heat of beryllium and Mixter and Dana that of zirconium.

Weinhold investigated platinum at high emperatures, using the air pyrometer, but his results are discordant, showing imperfections in his method, so that his results did not supersede those of Pouillet.

More recently, J. Violle made a study of platinum up to 1,200° C., using the method of mixtures, an air pyrometer and every refinement possible to ensure accuracy. His determinations are the best we have for this metal, and serve as the basis for calculating the temperature of the ball at the moment of immersion when working by the double method. Violle used platinum in this way for determining the specific heats of gold, iridium and palladium up to 1,200°. He also found the latent heat of fusion of platinum and palladium by determining the amounts of heat in the molten metal and in that just set.

Le Verrier (*Conservatoire des Arts et Metiers*) has recently investigated aluminum, copper, lead, silver, tin and zinc by the method of mixtures, using the recently-devised Le Chatelier pyrometer to determine temperatures, which it is stated can be done at the very moment of the immersion of the metal in the water of the calorimeter. He finds sharp variations in the specific heats of most of these metals, which no other investigator has seen any indications of, so that his results are very much doubted. Careful and very concordant experiments made by your lecturer on copper, by the double method, have failed to show any indications of variations at points indicated by Le Verrier, so that we must put on Le Verrier the burden of proving his results by repeating his experiments and giving all their details; in short, he must prove his position by further proofs before his results will be seriously considered as true.

Pionchon has done perhaps the most accurate work of

recent years in his studies of cobalt, iron, nickel, silver and tin (1886), and aluminum (1892). He worked by the double method of mixtures, using Violle's formula for calculating the temperature of the platinum. His results are very concordant except in the case of aluminum below 300°, where a variation of five per cent. between his formula and the experimental results would be possible. Otherwise, he has given complete curves for the specific heats of aluminum, cobalt, iron, nickel and silver to 1,200°, and tin to 1,000°, and determined the latent heats of fusion of aluminum, silver and tin.

An exactly similar set of experiments was made by your lecturer on aluminum, up to 600°, with a determination of its latent heat of fusion. In connection with Prof. B. W. Frazier, of our University, a similar set of experiments is now in progress with copper, the result of which will give the curve for its specific heat to the melting point, its latent heat of fusion and the specific heat of molten copper. The approximate values so far found are given in discussing copper. The calorimeters and apparatus used by Professor Frazier and myself are shown in the accompanying cuts. *Fig. 1* shows a section of the calorimeter. The outer box is walnut, the calorimeter proper is of thin brass, tightly covered, and packed in with cotton. The stirrer is of wire mesh, fitting closely to the walls, and provided with a glass rod for a handle. (Wooden rods warped and worked stiffly.) The thermometers are standard Baudin, graduated to 0°·02 and easily read with a lens to 0°·0025. The calorimeter is charged with about 300 grammes of water, and, using a platinum ball of fifty-two grammes, the rise in temperature is approximately 0°·5 for every 100° fall of the platinum ball. The corrections for losses of heat to the calorimeter during the experiment are made by a system worked out by us, which gives most satisfactory results, but which cannot be described in the limits of this lecture. Suffice it to say that the probable errors in the calorimeters themselves are within 0·1 per cent.

Fig. 2 shows the apparatus for containing the metals in the furnace. It is a piece of fire-brick, cut as indicated, and

with two smooth French annealing cups fastened into the holes. In operation, the platinum is put in one side, the other metal in the other, and the crucibles covered by porcelain lids connected by a stout platinum wire. The whole is then heated several hours at the desired temperature. Everything being ready, the two calorimeters are brought into the furnace room, and opened to receive the balls. The brick is withdrawn from the furnace, the lids are lifted off by the platinum wire. Then by inclining the brick between 45° and 90° first to one side and then to the other, the two balls are dropped one at a time, into their respective calorimeters. The stoppers are replaced, the calorimeters are carried to their room and readings are taken for five minutes. In order to avoid errors, a full experiment is made to consist of two separate ones made as nearly as possible at the same temperature, but with every condition reversed, which could affect the result; viz:

(1) The position in the furnace.

(2) The position in the brick.

(3) The order of dropping out of the brick.

(4) The calorimeter into which it is dropped.

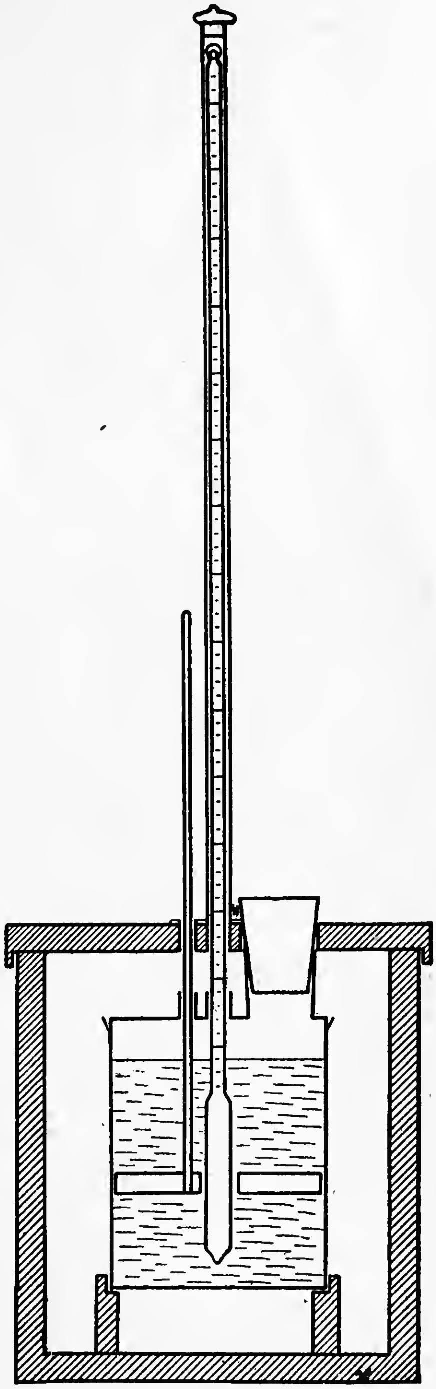


FIG. 1.

With these precautions, we have not rested satisfied until we have reduced the maximum difference between

corresponding experiments to *less* than one per cent., and the deviation from the mean to *less* than 0·5 per cent.

IV.

In general we may say that the only factor we really obtain by investigating specific heats by the method of mixtures, is the amount of heat given out by the substance in cooling through a certain range of temperature. The lower temperature is that of the calorimeter, which usually varies between 15° and 25°, while the upper temperature varies at will. If the results obtained for any one substance are plotted on a diagram, taking the range of temperatures as abscissas and the heat given out as ordinates, it is at once found for most metals that a straight line will not pass through the points. The heat given out increases in greater proportion than the temperature, giving a curve which is convex towards the axis of abscissas, gradually becoming steeper and steeper. The formula for such a curve must then be of this nature:

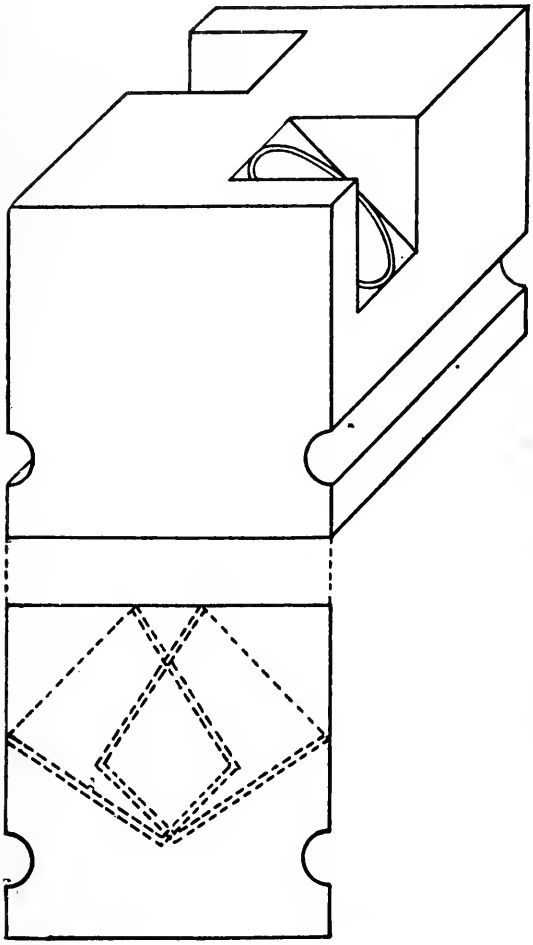


FIG. 2.

$$Q = \alpha t + \beta t^2 \tag{1}$$

in which Q represents the quantity of heat given out to zero, and t any temperature. If a curve of this nature does not rise sufficiently fast at high temperatures, a third term can be added, making it

$$Q = \alpha t + \beta t^2 + \gamma t^3$$

It has been found that allowing for errors of experiment formulæ of this kind will fit almost all the observations on specific heats so far made, and in most cases the formula of two terms answers perfectly. The third term seems to be needed only when the curve is approaching the melting point or a critical point of the substance. when part of the heat necessary for a change of state seems to be absorbed before the point itself is actually reached. At temperatures distant from these points only two terms are needed in the formula.

Suppose, now, that a series of experiments have been made with a metal, and it is wished from the data obtained to construct the formula reckoned to zero. For a body cooling from t_2 or t_1 to zero the formula gives

$$Q_1 = \alpha\, t_1 + \beta\, t_1^2$$

$$Q_2 = \alpha\, t_2 + \beta\, t_2^2$$

therefore, for a body cooling from t_1 to t_2, the amount of heat given out must be

$$(Q_1 - Q_2) = \alpha\,(t_1 - t_2) + \beta\,(t_1^2 - t_2^2) \qquad (2)$$

Having measured the quantity of heat given out in the different experiments between various high and low temperatures, the values of $(Q_1 - Q_2)$, t_1 and t_2 can be substituted in equation (2), and thus each experiment gives us some relation between α and β; therefore any two experiments will give us two equations from which the value of these unknown coëfficients may be derived. Two other experiments might give slightly different values for α and β, and thus several slightly varying values could be obtained and their average taken as the true values. A much neater and more accurate way, however, is to substitute in equation (2) the data obtained in each experiment, thus obtaining as many equations of condition as there are experiments made, and from these to calculate the most probable values of α and β by the method of least squares. The formula thus derived will give a curve which will pass through the mean of all the observations made.

If the heat given out by a substance in falling from t to zero be divided by the range of temperature t, the quotient is the mean value of the specific heat between those temperatures, therefore:

$$S_m = \frac{Q}{t} = \frac{\alpha\, t + \beta\, t^2}{t} = \alpha + \beta\, t \tag{3}$$

Or, if the substance falls from t_1 to t_2 instead of to zero,

$$S_m = \frac{Q_1 - Q_2}{t_1 - t_2} = \frac{\alpha\,(t - t_2) + \beta\,(t_1^2 - t_2^2)}{t_1 - t_2} \tag{4}$$

$$= \alpha + \beta\,(t_1 + t_2)$$

If we evaluate equation (2) for two temperatures within 1° of each other, we obtain the heat given out for a fall of 1°; that is, the actual or true specific heat at that temperature. A much more elegant method, however, is to take the first differential cöefficient of the equation representing the heat given out in falling to zero [equation (1)], and thus obtain the equation for the *ratio* of the heat given out to the fall in temperature, which ratio is the true specific heat.

Therefore, taking

$$Q = \alpha\, t + \beta\, t^2 + \gamma\, t^3$$

We have

$$S = \frac{d\,Q}{d\,t} = \alpha + 2\,\beta\, t + 3\,\gamma\, t^2$$

Or, leaving out the third term as before,

$$S = \alpha + 2\,\beta\, t \tag{5}$$

This formula is very similar to equation (3) for the mean specific heat, both of them being the formulæ of straight lines, starting when $t = 0°$ at the value α, which is therefore the true specific heat of the body at zero. The formula for the true specific heat can thus be easily deduced from that for the amount of heat; and it is this quantity which has an intimate dependence on the properties of the substance

at any given temperature. For this reason, the diagrams which follow show the variations of the *true* specific heat with the temperature.

[There were here thrown upon the screen a number of diagrams, with running comments by the lecturer. It has been thought advisable in printing the lecture to incorporate these diagrams into an Appendix, in which is discussed the specific heat of each of the metals separately at a length which would have been undesirable, and indeed impossible, during the delivery of the lecture.]

[*To be continued.*]

CAUSES OF FIRES.

BY C. JOHN HEXAMER.

[*Concluded from vol. cxxxv, p. 299.*]

CAUSES OF FIRES IN DWELLINGS.

Statistics on the causality of fires are very meagre. The best general tables we have in this country, are those of the *Chronicle.* Mr. P. A. Montgomery has made a number of interesting calculations from the *Chronicle* tables, published in 1892, his purpose being "to ascertain the relative importance of the *principal* causes of fires, peculiar to certain classes of risks, incendiarism omitted." Exposure fires also were not taken into account. The results reached in regard to *dwellings and tenements* showed the following table of causes of fires:

Chief Causes.	*Relative Percentage of Inherent Physical Hazard.*
Defective flues,	21
Matches,	9
Explosions, lamps,	9
Forest fires,	9
Sparks,	7
Stoves,	6
Gas jets,	3
Lamp accidents,	3

Chief Causes.	*Relative Percentage of Inherent Physical Hazard.*
Explosions, oil stoves,	3
Lightning,	2
Carelessness,	1
Open fireplace,	1
Fireworks,	1
Candle,	1
Accident,	1
Cigar stub,	1
Fire crackers,	1
Stove-pipe,	1
Ashes,	1
Furnaces,	1
Oil stove accident,	1

BOARDING HOUSES.

Defective flues,	18
Explosions, lamps,	16
Gas jets,	9
Matches,	8
Stoves,	7
Cigar stubs,	6
Sparks,	5
Open fireplaces,	3
Lamp accidents,	3
Ashes,	2
Explosions, oil stoves,	2
Carelessness,	1
Stove-pipe,	1
Candle,	1
Fireworks,	1
Furnace,	1
Spontaneous combustion,	1

A table, published in the *American Exchange and Review* (June number, 1892), shows that the number of fires in fifteen years (1876, 1878–1891) in dwelling houses in Massachusetts were 12,814, property loss $8,082,322, and the causes of the 1,213 fires in the year 1891 were reported as follows:

Ashes in wooden vessels,	12
Ashes from pipe and pipe in clothes,	27
Burning off paint,	1
Careless use of matches,	50
Children playing with matches,	101

Cigar stub in wooden spittoons,	5
Clothes near stove,	17
Curtains near gas or candle,	38
Defective chimney,	172
Exposure,	111
Electric wires,	3
Fireworks and fire crackers,	11
Fat boiling over,	2
Fumigating with sulphur,	4
Gas leaking,	4
Explosion of gas,	4
Hot iron on wood,	2
Incendiary,	54
Breaking lamp,	77
Breaking lantern,	3
Explosion of lamp,	50
Explosion of lantern,	1
Explosion of oil stove,	30
Lightning,	6
Mice and matches,	36
Overheated stoves,	50
Overheated steam-pipe,	1
Open funnel hole,	1
Plumbers' fire-pot,	7
Rags in funnel hole,	1
Sparks from chimney,	35
Sparks from locomotive,	12
Sparks from stove and fireplace,	14
Spontaneous ignition of rags,	10
Spontaneous ignition (cause unknown),	9
Soot igniting,	23
Starting fire with oil,	1
Thawing water pipe,	3
Tar boiling over,	1
Timber built into chimney,	1
Wood-work near stove,	6
Wood-work exposed to gas or candle,	14
Volatile oil (naphtha),	5
Smoking in bed,	9
Slaking lime,	1
Powder explosion,	1
Unknown,	187

In Massachusetts boarding and lodging houses, in the above-mentioned fifteen years, 150 fires occurred with a property loss $155,808.

CAUSES OF TWENTY-THREE FIRES IN 1891.

Defective chimney,	4
Curtain near gas,	2
Careless use of matches,	4
Smoking in bed,	2
Unknown,	5
Exposure,	2
Spontaneous ignition,	2
Overheated stove,	1
Mice and matches,	1

Perhaps it will be of local interest to compare the origins of Philadelphia's ash pile, costing $19,319,202.53 in a decade. The statistics contained in the annual report of the Insurance Patrol are worthy of investigation. In the April number of the *American Exchange and Review*, 1893, the results of the decade 1883–1892 have been compared. In order to reduce statistical quotations to a minimum, we quote now all the parts in this comparison we shall hereafter need.

As an approximation, the value of combustible property in the city of Philadelphia may be placed at $1,200,000,000; amount insured, $800,000,000—more than one-half of the insurance on dwellings and contents.

Fire loss in its aggregation is according to value of property per square foot of ground area under equal conditions, otherwise, of ignition, combustibility and fire extinguishment. In other words, loss is according to concentration of value. Philadelphia, like other modern cities, tends to concentrate values. Measured by decades, the fire history of the city shows from about $500 loss per fire to about $3,000 loss per fire. The data of three decades are as follows:

Decades.	*Total Fires.*	*Loss per Fire.*
1856–65,	3,679	$1,772
1866–75,	6,154	3,041
1883–92,	10,801	1,788

(In the decade 1866–75, a period of great manufacturing development, the conflagrative force of the city was at the highest point it has ever attained.)

From 1856 to 1892 the population doubled and combustible value trebled, but the city was burning at about the

same rate of combustion at the end as at the beginning of this period—notwithstanding growth of concentration with augmenting aggregation; an evidence of effective fire extinguishment and fire salvage.

The Patrol report enumerates the 1,410 fires in 1892 as burning $1,684 per fire. Increase in rate of ignition is notable. There were 114 more fires in 1892 than in 1891, with eighty-four more fires in dwelling-houses and fifty-one more fires in stores. The 1,278 fires of 1891 assailed $1,555,664 more insurance than the 1,410 fires of 1892, and the loss of 1892 was $298,901 less than that of 1891. The saving in fire cost in 1892 was due to stores and warehouses, which burned $540,979 less in 1892 than in 1891; woollen goods in 1891 burned more than double all the store and warehouse fires in 1892.

If we take the increase of Philadelphia combustible value from 1883 to 1892 as forty per cent., the $1,172,732 of fire loss in 1883 would have as its equivalent in 1892, $1,641,824, but

	Fires.	*Loss per Fire.*
1883, ...	853	$1,374
1892, ...	1,410	1,684

With 853 fires in 1883, the equivalent ignition in 1892 would have been 1,194 fires, and the excess of $735,639 in proportionate loss in 1892 was largely due to excess of ignitions. But in 1883, the combustive force was about one-half of that of 1884.

We cite the following annual comparisons of the decade, given in the Patrol report:

Years.	*Fires and Alarms.*	*Insurances.*	*Losses.*	*Per Cent.*
1883, ...	853	$8,054,985 00	$1,172,731 75	13·87
1884, ...	897	8,193,526 36	2,254,412 66	27·63
1885, ...	1,078	10,125,704 66	1,755,575 46	17·33
1886, ...	1,153	13,209,584 00	2,717,444 74	20·57
1887, ...	1,041	8,727,679 00	1,253,492 94	11·84
1888, ...	763	9,519,334 39	2,128,136 58	22·35
1889, ...	954	13,855,616 33	1,570,528 61	11·34
1890, ...	1,341	16,222,981 77	1,442,943 09	8·89
1891, ...	1,296	20,689,271 65	2,676,363 87	12·93
1892, ...	1,425	19,133,628 32	2,377,462 83	12·36
		$127,652,301 48	$19,319,202 53	15·11

The annual reports for the last three years of President Wagner, of the Philadelphia Patrol, present the following recapitulations:

BUILDINGS AND CONTENTS.

	1890.	1891.	1892.
Stores and Warehouses:			
Number of fires,	336	239	290
Insurance loss,	$218,186	$655,790	$114,801
Textile Works:			
Number of fires,	64	69	78
Insurance loss,	$404,322	$1,238,009	$1,191,432
Metal Works:			
Number of fires,	26	40	37
Insurance loss,	$1,429	$68,851	$63,904
Wood Works:			
Number of fires,	44	48	49
Insurance loss,	$385,075	$45,477	$168,456
Printers and Bookbinders:			
Number of fires,	1	13	9
Insurance loss,	$35,040	$209,836	$121,744
Dwellings:			
Number of fires,	543	485	569
Insurance loss,	$34,942	$29,313	$56,005
Stables and Barns:			
Number of fires,	60	59	60
Insurance loss,	$39,044	$52,000	$15,663
Churches:			
Number of fires,	9	3	6
Insurance loss,	$3,694	$12,169	$14,861
Miscellaneous:			
Number of fires,	222	331	312
Insurance loss,	$321,210	$344,898	$630,596

CAUSES OF FIRE IN PHILADELPHIA IN 1892.

Statement showing the causes of fires, number of fires from each, and the losses resulting therefrom:

Causes.	*No. of Fires.*	*Insurance.*	*Insurance Loss.*
Boilers,	13	$391,756 00	$6,271 76
Boiling over of fat, oils, etc.,	25	125,200 00	4,772 81
Bonfires,	11	9,900 00	2,433 00
Candles,	41	821,800 00	118,294 30
Defective flues,	128	668,700 00	12,103 35
Dry rooms,	5	139,200 00	55,967 64

Causes.	No. of Fires.	Insurance.	Insurance Loss.
Electric light wires, ...	17	$238,400 00	$16,597 44
Fire-pots (tinners'), ...	5	408,400 00	17,790 51
Fireworks, ...	36	241,100 00	2,736 68
Friction, ...	13	710,100 00	100,872 90
Gas jets, ...	71	2,105,199 00	300,330 14
Heaters, ...	23	244,080 00	5,756 65
Hot ashes, ...	19	93,800 00	3,601 16
Kilns, ...	3	583,500 00	131,224 53
Lightning, ...	5	443,000 00	10,043 41
Low-down grates, ...	5	24,000 00	689 00
Matches, ...	93	545,100 00	9,120 02
Oily rags, ...	5	138,500 00	6,162 35
Ovens, ...	8	51,300 00	566 00
Pickers, ...	24	623,700 00	5,289 24
Ranges, ...	19	55,500 00	1,262 45
Roasters, ...	3	79,700 00	2,161 88
Roofers' wagon, ...	1	25,250 00	5,464 99
Rubbish, ...	46	871,200 00	10,188 12
Smoking, ...	16	64,406 66	10,647 64
Sparks from emery wheel, .	1	61,500 00	7,907 64
grinder, . . .	1	9,500 00	2,995 80
locomotive, . .	23	132,100 00	20,156 42
Spontaneous combustion, .	26	588,700 00	227,802 38
Stoves, cook and parlor, .	93	310,275 00	22,818 96
Stove-pipes, ...	12	28,200 00	1,589 02
Supposed incendiary . . .	12	18,000 00	2,064 28
Suspicious, ...	10	217,900 00	43,116 27
Unknown, ...	230	4,339,556 66	1,148,634 21
Sundry causes, losses of which do not reach $500, .	126	2,425,820 00	2,337 05
Total, ...	1,169	$18,033,143 32	$2,319,770 00

Petroleum Fires:

Explosions of benzine, . .	9	$46,800 00	$5,193 15
coal oil, . .	5	12,250 00	355 75
gasoline, . .	6	17,450 00	523 25
naphtha, . .	1	51,400 00	200 00
Lamps, coal oil, ...	146	746,560 00	44,690 12
gasoline, ...	12	34,000 00	491 60
Overheated oil tank, ...	1	76,900 00	2,002 66
Stoves, coal oil, ...	21	40,325 00	1,901 85
gasoline, ...	40	74,800 00	2,333 45
	241	$1,100,485 00	$57,692 83
Total, ...	1410	$19,133,628 32	$2,377,462 83

We will now turn from bare figures to a more general description of the origins of fires in dwellings. One of the most prolific causes of fires is incendiarism. This is of two sorts, (1) by dishonest policy holders, and (2) by acts of revenge and pyromania, which I believe to be a variety of mental disease as prevalent as klopemania. There has been much debate on the amount of the former. To what extent the insurance companies are annually the losers through this crime it is impossible to say. A good system of fire coroners in our country would do much to lessen the number of such losses, as well as to give us more reliable statistics. Australia, which has led the English-speaking world in many useful reforms, has tried this system. The following editorial notice in the *Chronicle* (April 13, 1893) gives us an idea of the results to be expected and the importance of the work.

"The *Australasian Insurance and Banking Record* publishes a record of inquests on fires in New South Wales in 1892, which should interest the fire inquest people in the United States. The total number of inquests was 139, but in ninety-one cases the evidence was so incomplete that the fire coroners could not decide whether the fire originated accidentally or was caused by an incendiary act. Out of forty-eight cases in which the coroner reached conclusions, nineteen fires were decided to have had accidental origins, while twenty-nine fires were attributed to arson. In other words, sixty per cent. of the fires whose causes were ascertained were incendiary and the remaining forty per cent. accidental. This abnormally large percentage of incendiarism will create surprise, even among those American fire underwriters who are most suspicious of the honesty of policy-holders. The Australasian coroners' decisions would appear more trustworthy if the proportion of their indecision was not so large. No information is given by the *Record* as to the number of alleged incendiary fires in which insurance policies were involved."

Man's domestic customs and habits undergo fewer mutations than do the operations of his business life.

In the latter he is quick to appreciate and to follow im-

proved methods, but in the construction of his dwellings and in his manner of life within their walls he clings tenaciously to practices which have long outlived their usefulness.

It is our purpose to confine ourselves at present to a consideration of the *causes* of fires, interesting as might be a study of the historical evolution of our dwelling-houses, a comparison of our homes with the *οἰκία* of the Greeks, or with the houses and *insulæ* of the Romans, with whom the tenement house, generally supposed to be a modern institution, was not wanting, or a contrast between the English homes of the time of Shakespeare (so charmingly described by William Harrison, in *Hollinshed's Chronicles*, 1577, Book II, Chapter 10; 1587, Book II, Chapter 12,) and those of the present day. But why, it is pertinent to inquire, do we not introduce in our dwelling constructions the slow-burning principles now universally employed in properly built manufactories, many of which could advantageously be utilized without deteriorating the æsthetic effect?

The majority of fires in dwellings are caused by heating and lighting apparatus.

The heating apparatus of a house should be centralized as much as possible. One fire is by far less hazardous than a number of them, for every one is an additional source of danger. Whatever system may be used, whether hot air, steam, or hot water, great care must always be exercised that inflammable substances are not placed in the immediate neighborhood of the heating apparatus.

Two things in every household, which frequently fail to receive the proper amount of attention, and which, in view of their importance, should be erected only by the best workmen, are the systems of drainage and heating. A defect in the first menaces health, and in the second involves danger from fire. We frequently find that in erecting heating apparatus, no thought has been given to the fact that heat will expand substances, and especially metals, to a considerable degree. This negligence in construction causes the formation of cracks and breaks which allow sparks to penetrate into the surrounding air. Where hot-air registers are used in floors (if possibly avoidable do not have them) cover the openings

with wire netting; especially in places where dirt and other refuse are apt to drop in, or where children could throw inflammable substances into them. At least one register in every house should be so arranged that it cannot be closed, for many fires are caused by hot-air flues becoming overheated when all registers are closed and the hot air cannot escape. Strict cleanliness in every detail of heating arrangements, is of prime importance, and before "firing up" in autumn the entire apparatus should be thoroughly examined. New heating apparatus is especially dangerous, as it has not stood a trial. Be specially on the alert in very cold weather, as artificial heating must then be increased to a dangerous degree.

Separate stoves should not be put up in out-of-the-way rooms. See that your central heating apparatus gives satisfaction, as frequently these stoves are neglected and cause fires. Stoves should be free from cracks and the floor protected by pieces of metal under them. These metal protectors should be amply large, so that hot coals which may fall from the stoves may be received on them, and not fall on the wooden floor or carpet. Brick platforms are not as safe as tin, as stoves are not apt to remain as stable on brick as on metal. Stoves should never be placed on ash receptacles, as they afford little stability and tend to cause stoves to lean and upset. The plastering of walls around stoves should be unbroken, and particular care should be taken that laths are not exposed to the escaping sparks. Wood-work near stoves should be protected with bright tin, which acts as a reflector to the heat rays, while a black or rough surface absorbs them. The storing or piling of wood near stoves is a frequent cause of fires. Particular care must be paid to stove-pipes to keep them at all times sound and in good order. They should never enter chimneys at points which cannot at all times be inspected, such as unused rooms, closets, and the like; nor should a stove-pipe extend through any place where it is not at all times visible, as fires may be caused by the accumulation of dust and fine organic matter upon it. The tops of

stove-pipes should be frequently looked after and cleaned. The joints or elbows of pipes should be well riveted, so that sparks may not be ejected through the breaks, and the entire pipe should be well supported by wire hangers or braces. Where pipes pass into chimneys they should be well fastened by a metal or terra-cotta collar, which, as well as the pipe, should be tightly wedged into the opening so that the pipe cannot disengage and thereby emit sparks into the room. Care must be taken never to allow stove-pipes to enter a flue vertically, as soot which may accumulate in the pipe is readily ignited and may cause larger fires. Stove-pipes should never pass out of the sides of a building or through windows.

Ashes should be kept in metal receptacles, never in wooden, or as is sometimes the case, in pasteboard boxes. Ashes have the remarkable property of holding heat for a long time, and for this reason ashes which are seemingly cooled should never be placed in wooden barrels and stood alongside of frame buildings or fences, as several cases are known in which spent ashes on being piled in quantity again became heated and ignited adjacent wood-work. All chimney flues should be properly "pargeted" on the inside, the brick-work should be of sufficient thickness between the floors or studding, and all wood-work should be well trimmed away from flues with safe air spaces between. Before plastering the inside, however, the architect, or better still, the proprietor, should see that the bricks of the chimney are solidly laid in mortar and well pointed. Many chimneys are laid almost dry, and when the plastering drops off such chimneys become exceedingly dangerous.

Instead of laying brick or stone on planks and flooring to form hearths, the latter should be protected by brick arches. This is the safest method. If brick arches cannot be so placed, then a layer of thick asbestos paper or concrete should first be laid on the wood-work, upon this a layer of sand and concrete, and then bricks laid in good cement; upon this another layer of bricks should be laid, but in such a manner as to leave an air space between it and the preceding course.

The safest system of heating is by hot water. In this case, the room is heated by radiation from pipes filled with water which has been heated in a boiler, preferably outside of the building to be heated.

Steam is now frequently employed for heating dwellings. Special care must be taken to hang pipes free from wood-work and away from all places where dust, dirt, sweepings and so on may accumulate. Where it is possible, as in tenement houses, servants' apartments, store-rooms, etc., steam pipes should be hung along the ceiling, about twenty-four inches below it (as is the usual method in the best modern factory buildings), instead of along the sides of the room as in the old fashion. The theory, often advanced, that with pipes hung below the ceiling, the same amount of heat cannot be obtained as when placed along the sides of the room, is erroneous. The following table, which shows the results of a series of experiments made by Mr. C. J. Woodbury, demonstrates this.

Hourly thermometrical observations were taken in a room 75 x 400 feet, supplied with five rows of steam pipes. In the first instance, the pipes were placed against the walls near the floor, and in the second there were four rows of pipe around the room, two feet from the walls and hung the same distance below the ceiling, requiring only three-quarters as much pipe as in the first instance.

MEAN TEMPERATURE OF HOURLY READINGS.

Thermometers Hung in Centre of Room.	Degrees Fahrenheit.	
	Pipes at Side. Dec. 29th to Jan. 5th.	Pipes Elevated. Jan 29th to Feb. 5th.
Sixteen inches from ceiling,	80·05	80·80
Midway,	76·52	76·90
Sixteen inches from floor,	77·08	77·00
Average,	77·88	78·23

The reasons why steam pipes ignite wood are twofold: (1) By allowing the water to run low, the steam becomes superheated, causing a true combustion, and (2) pipes

containing steam at the usual temperature may cause the secondary phenomenon of spontaneous combustion. In the latter case, the steam pipes slowly dry the wood, the contained moisture being vaporized, and at last the wood assumes a state resembling charcoal; whereupon the glowing or combustion, well known in the case of charcoal, takes place spontaneously.

At a discussion of the French Academy, in 1879, this was brought out clearly. M. Cosson described an accident which had occurred in his laboratory a few days before. While the narrator was working in the laboratory, a portion of the boarding of the floor spontaneously took fire. The boards were in the vicinity of an air hole, fed with warm air from a stove four metres away on the floor below. A similar accident had taken place a few years before, and in consequence M. Cosson had replaced the boards adjoining the air hole by a slab of marble. The boards which now ignited adjoined the marble. The heat to which the boards were subjected was, however, very moderate, being only that of warm air at 25° C. Nevertheless, M. Cosson said the wood had undoubtedly been slowly carbonized. Being thus rendered extremely porous, a rapid absorption of the oxygen of the atmosphere had resulted and sufficient caloric was thereupon produced to originate combustion. The danger thus disclosed, said M. Cosson, is one to which the attention of builders ought to be directed. In the instance in question, M. Cosson was able to extinguish the fire with a little water, as he was present and witnessed its beginning; but had it occurred at night, during his absence, it would undoubtedly have completed its work of destruction. M. Fayé stated that at Passy, a few days before, a similar case of spontaneous fire, due to the action of the warmth from the air hole of a stove upon the woodwork, had occurred at the house of one of his friends.

Mr. C. C. Hine, the veteran editor of the *Monitor*, expatiates on this topic as follows: "The Institute of Technology, of Boston, long ago decided upon the danger of steam pipes passing through and in contact with wood. It was shown that the wood, by being constantly heated, assumes the

condition, to a greater or less degree, of fine charcoal, a condition the most favorable to spontaneous combustion. This is so important and interesting a point that we may be pardoned for enlarging upon it somewhat in contrast to the brevity of the foregoing paragraphs.

"Steam was generated in an ordinary boiler and was conveyed therefrom in pipes which passed through a furnace and thence into retorts for the purpose of distilling petroleum. Here the pipes formed extensive coils and then passed out, terminating at a valve outside the building. To prevent the steam, when blown off, from disintegrating the mortar in an opposite wall, some boards were set up to receive the force of the discharge, and as often as the superheated steam was blown against them, the boards were set on fire! This occurred in an oil refinery in Pittsburg, Pa.

"Some years since, while on a visit at the Institution for the Deaf and Dumb, in Illinois, of which an esteemed friend is principal, we called attention to the manner in which some steam coils were secured to wooden supports, and pronounced them unsafe. They were shown to be a thousand feet or so—as the pipes ran—from the boiler, and our caution only provoked a smile. The next year we visited, as usual, and, upon taking the principal's hand, he said—before exchanging salutations or inquiries: 'Come with me; I wish to show you something,' and led the way to the room where, a year ago, his attention had been called to the steam pipe. 'There,' said he, 'examine that; I have been saving it for you since last winter; the coil fell down, and investigation showed that the screws had let go because the wood had been turned to charcoal and had no more strength to hold them.' The experience was new to him; it may be old to some of our readers, but its introduction here will illustrate a fact which is now becoming an admitted one among those who have given this matter attention.

"An experiment illustrating the effects of superheated steam was tried as follows: Steam was taken from an ordinary boiler through a pipe forty feet long. Ten feet from the farther end a collar of wood was fitted closely to the pipe; ten feet nearer the boiler a lighted kerosene lamp

was placed under the pipe. In ten minutes the wooden collar was on fire."

To resume our text, then, carelessness causes the greatest number of fires: carelessness in regard to heating, and lighting and in storing inflammable and self-inflammable substances. We pass now to the next series of hazards, those of lighting.

The usual method of lighting in the larger cities of America is by gas. The greatest care must be taken to arrange fixtures so that they cannot swing against combustible substances, such as curtains and woodwork. Swinging brackets are largely responsible for fires in dwellings, and should, as much as possible, be done away with. A gas flame is the producer of intense heat, tending to thoroughly dry all substances around it and transform them into a state ready for ignition. A systematic arrangement and solid construction of the entire system of gas supply throughout a house is of prime importance. Frequently, the installation of gas fittings is left to "cheap" employés or apprentices, and this, of course, carries serious results with it. Not only do fires originate through leaking gas pipes, but many lives also have been lost by gas poisoning and suffocation. A valve which cuts off the main supply, to which any member of the household can readily have access, and which *can be turned without trouble*, is of great importance, as sometimes it is impossible to stop leaks without the aid of a mechanic, and fires have been caused by persons going into rooms with lights "searching for the leak." They usually find it by this method; not, however, in a manner agreeable to themselves.

In installing a system of gas lighting, particular attention must be paid that every gas flame, which, through the heat which radiates from it, forms a certain globe or radius of danger around it, is at a safe distance from inflammable substances. A gas flame should be at least thirty-six inches from the ceiling, and when nearer to an inflammable substance than this, the latter should be covered with metal, care being taken to allow an air space between the metal and the wood or other inflammable substance, so that it

cannot be ignited or charred by conduction, which might otherwise be the case. Where swinging brackets are used (avoid them wherever you can), these should be provided with stops to prevent them from swinging against woodwork. A very good method of arranging gas lights, which has not been carried out in dwellings, but which is required in theatres, is to place wire baskets or cages around them. These cages are made of wire, and attached to the bracket. The gas can be readily lit by protruding a lighted taper or match between the wires (electric lighters now generally introduced make the ignition of gas still easier) while the globe of wire prevents combustible substances from coming in contact with the flame or inside of the sphere of danger. Such cages should by all means be fastened to those long swinging brackets in chambers, which are usually found near windows on both sides of looking glasses. It will be objected that the wire guards in theatres are unsightly, but these devices could be made of brass in beautiful designs so as to be an ornament. If a window be opened a draught blows the lace curtain into the flame, and a fire results. This winter, a number of fires were caused in Philadelphia by persons who in attempting to light the gas from such brackets near window curtains, succeeded in igniting the latter.

Where Siemens regenerative burners are used, ventilating flues should carry off the heat generated and the products of combustion. These flues should be well constructed of metal, free from woodwork, as large burners of this kind give off a great amount of heat.

Petroleum is much used for lighting in smaller dwellings, and in reading lamps, thanks to Philadelphia gas, even in finer residences. In order to be fit for use it should have a flash test of at least 130°. This can readily be tested by pouring some of the oil into a dish placed on a layer of sand contained in another receptacle, so that the heat may be distributed evenly throughout the oil, applying heat to the outer receptacle containing the sand, and placing a thermometer in the oil. An ignited taper (the flame as small as possible, so as not to heat the oil on the surface) is then held above

the oil, but not allowed to touch it. The temperature of the oil is then accurately observed, and if the vapor from the oil flashes before it has a temperature of 130°, it is unfit for use in households.

It is exceedingly difficult to extinguish petroleum fires, and the explosiveness of this substance is well known, as there is scarcely a week, or even a day, in which we do not hear of some sad accident caused by this substance. *Do not, therefore, attempt to light fires with petroleum.*

Dr. Schlumberger, who has given his special attention to this subject, some years ago stated that, according to the statistics which he had collected, out of ten persons who attempt to extinguish burning petroleum, six are killed.

Frequently dealers adulterate oils by mixing heavy oils with lighter and more explosive products. Petroleum is composed of the elements of carbon and hydrogen, and its products range, by almost imperceptible degrees, from oils which are very light and inflammable, to those of a consistency of molasses, which can only be ignited at very high temperatures.

The following are the principal products obtained by the distillation of crude petroleum, but chemists have obtained by fractional distillation many other substances holding intermediate positions in the list and to these they have given as many different names.

	Specific Gravity Water, 1.	Specific Gravity Baumé.	Boiling Point. Fahr.
Rhigolene,	·625	—	65°
Gasoline,	·665	·85	120°
C-Naphtha,	·706	·70	180°
B-Naphtha,	·724	·67	220°
A-Naphtha,	·742	·65	300°
Kerosene oil,	·804	·45	350°
Mineral sperm oil,	·847	·36	425°
Neutral lubricating oil,	·883	·29	575°
Paraffine,	·848 (?)	—	—

The explosiveness and inflammability of an oil, however, do not depend upon its specific gravity, for the oil may not

be a stable one but a mixture of a lighter and a heavier oil, so that while the hydrometer may show its specific gravity to be comparatively high, it may be an extremely dangerous oil, as, on a slight elevation of temperature, the lighter constituent will be given off in the form of vapor.

[*To be continued.*]

THE COMMITTEE ON SCIENCE AND THE ARTS OF THE FRANKLIN INSTITUTE.

REPORT NO. 1706.

Subject—MARKS' IMPROVEMENTS ON ARTIFICIAL LIMBS.

At the stated meeting of the Committee on Science and the Arts of the Franklin Institute, held February 1, 1893, the following report was adopted and ordered to be issued over the signature of the Chairman and the certification of the Secretary, viz:

This invention consists of an improved method of making artificial limbs, adapted to amputations in the ankle, or below, in the tarsus or metatarsus in which the former modes of construction, with articulated ankle joints of wood as the material, were impracticable and unsatisfactory in result; although sometimes made when wood was employed as a material, these were always clumsy, and when the articulated ankle was attempted, it proved inoperative. The new method of construction involves the use of aluminum as the material to form the shell socket or sustaining frame, as it might be called, the aluminum shell supporting the body, and forming the attachment for the elastic rubber foot, which acts as a rolling elastic segment simulating the functions of the natural foot in walking, and acting as an elastic cushion in relieving the wearer from the jar or shock of resting the weight upon the limb. At the same time they resemble the form of the natural foot more closely than was possible with previous constructions.

The invention is described and set forth in United States Letters Patent, No. 470,431, to George E. Marks, of New York City, N. Y., dated March 8, 1892.

The specimen submitted to the committee shows the invention to be extremely light and so compact as to make no noticeable enlargement of the artificial foot beyond the size of the natural foot, thus completely restoring the appearances. The elastic portion of the foot is attachable and removable, and by its own elasticity retains its position upon the aluminum shell or form.

Your committee has examined the limbs in the course of manufacture, and as completed and as in use by wearers. When clothed, they give no indication in walking that they are not natural feet. Of course, there is not that extension which an ankle joint provides when the wearer is sitting, which, sometimes, and often occurs in the natural foot under such conditions, but this is true of all artificial limbs, unless special pains and an awkward effort is made to produce this motion. An artificial ankle joint requires pressure upon the heel to extend the foot.

The mode of making the aluminum shells consists in first producing a plaster cast of the mutilated member to which it is to be applied. Upon this plaster cast is fitted a pattern carved in the usual manner from wood, and prepared by varnishing for the founder. The aluminum shell is then cast from this pattern in a sand mould, removed from the mould when cold, and filled, straightened and polished with the usual workshop appliances, so that the shell of the limb is an internal piece of metal.

The extreme lightness of the metal is not the only advantage; there is also another of great importance. The aluminum does not absorb moisture, is not corroded by perspiration, or the excretions from the skin, or from the sores which unfortunately are too often found in a mutilated member, and it is readily cleansed by washing, not being liable to injury from water or moisture, or the heat incident to any climate. The leather portions are so readily detached, renewed and attached as to give promise of a far longer term of usefulness with less expense and trouble than has heretofore been attained in any other structure for the same purpose.

The drawing appended shows the invention in sections.

The elastic rubber foot is applied and renewed in the same manner and with the same facilities as an elastic overshoe.

The limb embraces four elements: First of these is the metallic shell or frame: its functions are to receive the weight of the wearer at its upper part, and transmit it to the foot.

This is the most expensive part of the structure, is not susceptible of corrosion under any conditions in which it is subjected in use; is strong, light and compact, and conforms closely to the form and dimensions of the limb which it simulates, and is of great durability.

The second is the removable elastic foot: this is so proportioned in thickness in its several parts as to hold securely

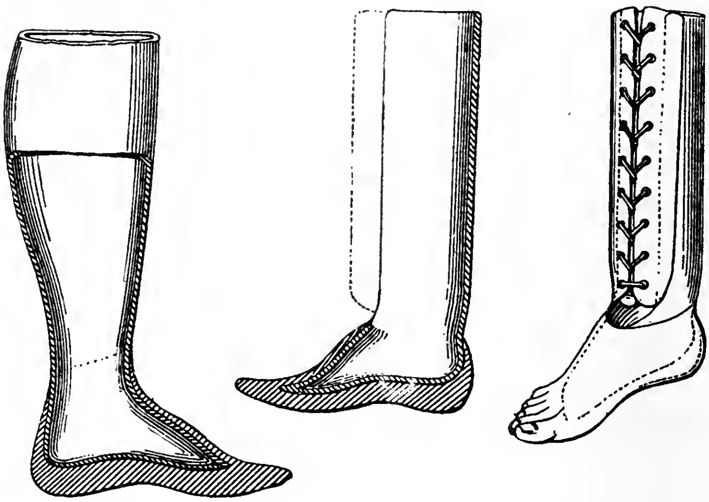


FIG. 1.

on the lower portion of the frame and to act as an elastic cushion in receiving the weight upon the heel and transfer it as the step progresses to the ball of the foot and toes, which, under the pressure, flex, and again extend as they are relieved of weight, thus closely imitating the action of the natural foot.

Being removable as easily as a rubber shoe, a new one from the same mould can be promptly and cheaply substituted when the original is worn out.

The third element in the structure is the leather jacket which confines the limb in the metallic shell or frame so that the weight is received on the upper portion.

This jacket of leather is attached to the shell by a few rivets, which can easily be removed and a new leather expeditiously substituted at small cost by any saddler or other leather worker without entailing the delay of sending the limb to the original manufacturers.

The fourth and last element is the pad in the base of the cavity of the aluminum shell or frame; this is not designed to support the weight of the wearer and does not necessarily make any contact with the stump, but is merely a protection to the wearer from the sensation of cold incident to close proximity of the metal.

The pad is made of cork in the specimen submitted and covered with felt on the upper surface, a pad of wool or any

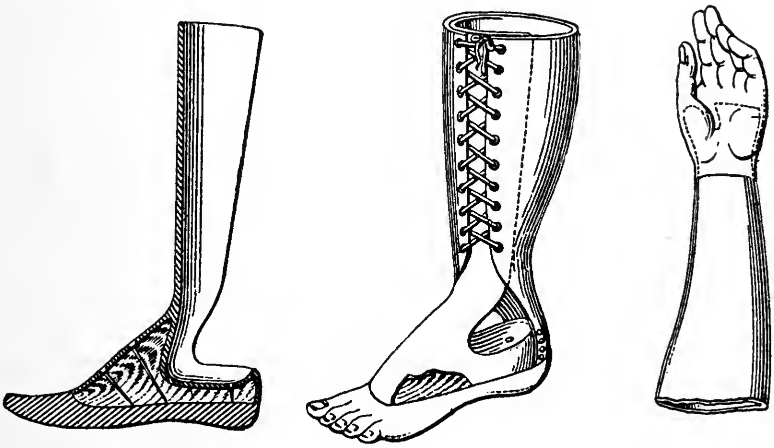


FIG. 2.

other similar substance could be substituted with like effect; the cork has the advantage of being light, and is easily removed, cleaned and replaced.

The combination of these parts forms a limb which, with inexpensive repairs, easily procurable with little delay, has almost unlimited durability and affords a much needed relief to many who heretofore were dependent upon crutches for aid in locomotion.

The invention, regarded from a humanitarian standpoint, is of great importance. Although it was less than two years from the making of the first specimens, at the time this invention was shown at the Institute and referred by resolution to the committee for examination, yet 134 at that

time had been brought into practical use, as appears from an inspection of the books and correspondence of the manufacturers, and all of them found to be satisfactory in performance.

Such a practical endorsement from the users and those only fully qualified to test the merit of this class of inventions is indicative of the great merit and suggestive of the extended field of usefulness of the invention.

The following, from the impression of the *New York Medical Journal*, of April 16,1892, sets forth better the importance of the invention from a humanitarian standpoint, as viewed by surgeons than your committee feel competent to express in any other terms:

"There are amputations of the lower limbs that surgeons deem desirable to do without sacrificing more of the member than the parts involved. We refer to amputations technically termed tibio-tarsal, tarso-metatarsal and medio-tarsal. These amputations have always been in disfavor with artificial limb makers, who have almost unanimously decried them, and, in too many instances, have persuaded the surgeons to sacrifice much of a healthy leg merely to obtain a stump that would better accommodate the artificial limbs that they were able to produce.

"The new artificial leg, constructed of aluminum combined with the rubber foot, is adaptable to these amputations. The socket of aluminum incases the stump, and on account of the strength of the metal the socket does not increase the diameters of the ankle to an objectionable degree in order to obtain the requisite strength. The metal is cast into the proper shape to give ease and comfort to the wearer, the aluminum socket is terminated by a rubber foot, which not only simulates the natural foot, but provides a soft springy medium to walk upon and a resistent phalangeal ball to rise upon while walking, running or ascending stairs.

"It is obvious that by this invention the amputation can be conditional upon the injury and the artificial limb conditional upon the amputation. In this alone the invention of the aluminum and rubber leg will prove not only a boon to the one who has suffered the amputation, but the solution of a problem that has many times perplexed the operating surgeon, as it eliminates all the objections heretofore pressed against amputations in the region of the tarsus. The surgeon may thus rejoice in being able to observe the old and consistent law of amputating with the least sacrifice."

It is, therefore, clearly apparent that the invention is one affording much needed relief to persons heretofore greatly embarrassed, and further that the surgeons may save much more of the patient's body from mutilation than heretofore,

and yet render comfortable and satisfactory artificial limbs practicable.

In view of these points of excellence and the well-attested evidence thereof, the committee awards the Elliott Cresson Medal to George E. Marks, of New York, for his improvements in artificial limbs.

Adopted, February 1, 1893.

H. R. HEYL,
Chairman Committee on Science and Arts.

Certified as a correct copy.

W. H. WAHL, *Secretary.*

THE CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the special meeting held Thursday, June 8, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 8, 1893.

DR. WM. H. GREENE, President, in the chair.

The object of this meeting was to afford the members the opportunity of hearing a lecture by Dr. Ernest Milliau, Director of the Government Testing Laboratory at Marseilles, France, on "The Methods of Testing Fats and Oils."

The lecture was delivered for the purpose of furthering the adoption of uniform methods of testing and of expressing results.

A vote of thanks to the lecturer was carried, and it was voted also to refer the lecture for publication in the *Journal* as part of the proceedings of the Section.

Adjourned. WM. C. DAY, *Secretary.*

[*Proceedings of the Stated meeting, held Tuesday, June 20, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 20, 1893

DR. WM. H. GREENE, President, in the chair.

Letters from Prof. E. F. Smith and Mr. Lee K. Frankel were read, expressing regret at their inability to be present at the meeting.

The President announced the death of Mr. C. J. Semper. Dr. Terne spoke of the work and character of the deceased, and the President

appointed Dr. Terne and Dr. Wahl members of a committee to prepare a memorial; he also gave them authority to appoint a third member.

The proceedings of the special meeting of the Section, held June 8th inst., were ratified by a unanimous vote.

Dr. Terne then read a highly interesting paper on "The Rational Utilization of City Garbage." This paper was very opportune, in view of the steps now being taken in Philadelphia to cremate and thus totally destroy garbage for sanitary reasons. Dr. Terne advocated the adoption of a system by which a saving of the valuable oil and fat ingredients of garbage could be effected, while the residue from this could be utilized as a valuable fertilizer. The members of the Section were unanimous in indorsing the view of Dr. Terne that garbage could be so utilized with a saving of much valuable material which is ordinarily wasted, and under the system of cremation totally destroyed. They also agreed that the ends of sanitarians would be just as effectively secured by the proposed system as by the wasteful process of cremation. The author further described some of the details of treating the garbage for the purpose he advocated, and exhibited samples of products, such as oils, solid fats and fertilizing material, which he had already secured on the large scale.

The Secretary then read a paper by Mr. Lee K. Frankel on "Gelatinous Silver Cyanide," and also exhibited a specimen of the compound submitted by the author.

The Section then adjourned.

WM. C. DAY, *Secretary.*

A LIST OF ELECTRICAL JOURNALS, 1893.

Compiled by Carl Hering.

AMERICAN.

Title.	*Published Where.*	*When.*	*Subscription.*
Electrical World,	New York.	Weekly.	$3 00
Electrical Engineer,	New York.	Weekly.	3 00
Western Electrician,	Chicago.	Weekly.	3 00
Electrical Review,	New York.	Weekly.	3 00
Electricity,	New York, Chicago.	Weekly.	2 50
Electrical Age,	New York.	Weekly.	2 00
Mechanic and Electrician,	St. Louis.	Weekly.	2 00
The Railroad Telegrapher,	Vinton, Ia.	Fortnightly.	1 50
Practical Electricity,	Boston.	Fortnightly.	2 00
Trans. Amer. Inst. Electrical Engineers,	New York.	Monthly.	5 00
Electrical Power,	New York.	Monthly.	2 00
Popular Electric Monthly,	Chicago.	Monthly.	1 00
Electrical Progress and Development,	Boston.	Monthly.	2 00
World's Fair Electrical Engineering,	Chicago.	Monthly.	
Electrical Industries,	Chicago.	Monthly.	
Mechanical and Electrical Progress,	Philadelphia.	Monthly.	
Journal of the Telegraph,	New York.		
Electric Spark,	Chicago.	Monthly.	1 00
Northwest Electrician and Mining Review,	Tacoma.	Monthly.	1 00
Bubier's Popular Electrician,	Lynn.	Monthly.	50
Electricity and Railroading,	Boston.	Monthly.	1 00
Street Railway and Electrical News,	Minneapolis.	Monthly.	2 00

FOREIGN.

In the English Language.

			(*In the U. S.*)
Electrician,	London.	Weekly.	19*s.* 6*d.*
Electrical Engineer,	London.	Weekly.	13*s.* 0*d.*
Electrical Review,	London.	Weekly.	£1 1*s.* 8*d.*
Electricity and Electrical Engineering,	London.	Weekly.	
Lightning,	London.	Weekly.	
Canadian Electrical News,	Toronto, Montreal.	Monthly.	$1 00
Journal of Institution of Electrical Engineers,	London.	Monthly.	
Electrical Plant (Electrical Industry),	London.	Monthly.	6*s.*

In the French Language.

Title.	*Published Where.*	*When.*	*Subscription.*
La Lumière Électrique, ...	Paris.	Weekly.	60 francs.
L'Électricien, ...	Paris.	Weekly.	25 francs.
Électricité, ...	Paris.	Weekly.	15 francs.
Bulletin de l'Électricité, ...	Paris.	Weekly.	15 francs.
Journal du Gaz et de l'Électricité, . . .	Paris.		
L'Industrie Électrique, ...	Paris.	Fortnightly.	26 francs.
Bulletin de la Société Internationale des Électriciens, ...	Paris.	Fortnightly.	27 francs.
L'Électricité pour Tous, ...	Paris.	Fortnightly.	6 francs.
Journal Télégraphique, ...	Berne.	Monthly.	
Bulletin de la Société Belge d'Électriciens, ...	Belgium.	Every 2 months.	
Bulletin de l'Association des Ingenieurs Électriciens Sortis de l'Institute Électro-Technique Montefiore, . .	Belgium.	Quarterly.	

In the German Language.

Elektrotechnischer Anzeiger, ...	Berlin.	Bi-weekly.	10 mark.
Elektrotechnische Zeitschrift, ...	Berlin.	Weekly.	25 mark.
Elektrotechnische Rundschau, ...	Frankfurt.	Fortnightly.	10 mark.
Elektrotechnisches Echo, ...	Magdeburg.	Weekly.	
Zeitschrift für Elektrotechnik, ...	Vienna.	Fortnightly.	

BOOK NOTICES.

Municipal Improvements. A Manual of the Methods, Utility and Cost of Public Improvements for the Municipal Officer. By W. F. Goodhue, Civil Engineer. First edition. First thousand. New York: John Wiley & Sons. 1893.

In this little work the author proposes to place in the hands of the intelligent and well-meaning but as yet uninstructed city councillor or other person charged with some responsibility for the construction and maintenance of public works, a guide to a general and correct understanding of the subjects with which he in his official capacity has undertaken to deal.

The author has used good judgment in the selection of his subjects, the amount of information to be imparted respecting each and the manner in which it should be presented. He has wisely avoided the danger, ever present with the writers of such works, of saying too much, and has, perhaps, erred a little on this safe side. Considering the character of his audience, we are inclined to think that a little too much information on their part respecting the A, B, C's is taken for granted.

Certainly the list of illustrations might have been advantageously

extended. There are but seven cuts in all—a diagram of cellar drainage being all that is given to illustrate "A Sewerage System," a diagram of stand-pipe connection for "A Water Works System"—and so on.

Still, the book, which is well got up, ought to be well worth its cost to the conscientious ones among those for whom it is intended. T.

Laboratory Calculations and Specific Gravity Tables. By John S. Adriance, A.M. Second edition. New York: John Wiley & Sons. 1893.

This book, of 114 pages, contains many tables useful to chemists. The title indicates its character. We will take the liberty here of pointing out one or two errors. On p. 46 is given a table showing the specific gravities corresponding to degrees Beaumé, for liquids heavier than water. In it, 66° B. equals sp. gr. 1·767. This is incorrect for the instruments used in the United States, where 66° always corresponds to 1·8354 sp. gr. The correct table will be found printed on the green case in which the instrument is packed.

Again, on p. 36, we find a table for converting milligrams per litre to grains U. S. gallon; on p. 94, a table of fluid measure, in which 160 fluid-ounces equals one fluidgallon, thus showing that the Imperial gallon is referred to; and, on p. 96, we have again the U. S. gallon of 231 cubic inches. This confusion of American and English measures should be avoided, by stating which gallon the table refers to. P.

Franklin Institute

[*Proceedings of the stated meeting, held Wednesday, June 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 21, 1893.

JOSEPH M. WILSON, President, in the chair.

Present, thirty-five members and five visitors.

Additions to membership since last report, nine.

The Secretary read a report signed by Messrs. Joseph M. Wilson, Henry R. Heyl, Jno. C. Trautwine, Jr., and George V. Cresson, constituting a special committee appointed under a resolution of the Institute, passed at the stated meeting of March 15, 1893, to examine and report upon the proposed amendments to the regulations of the Committee on Science and the Arts. The Special Committee reported that they had performed the duty assigned to them, and "found that the proposed regulations are in conformity with the charter and by-laws of the Franklin Institute, and in no respect conflict with the same." The committee recommended "that the proposed regulations be approved by the Institute, and ask to be discharged."

The report and recommendation of the Special Committee were, thereupon, on motion, adopted and the committee was discharged.

The Secretary read a letter from Mr. George V. Cresson, accepting his election as a Trustee of the Elliott Cresson Medal Fund, in place of Mr. Samuel Sartain, resigned.

The Secretary reported a vacancy in the Committee on Science and the Arts caused by the death of Mr. Walter H. Balliet. Mr. J. Logan Fitts was elected to fill the vacancy.

Mr. Thomas Shaw described and exhibited in operation an apparatus of his invention for determining the explosive force of gunpowders for small arms. The subject was, on motion, referred to the Committee on Science and the Arts, for examination and report.

Dr. Bruno Terne presented in abstract a paper treating of the question of the disposal of the garbage of large cities. The speaker discussed the relative merits of the system of cremating such refuse materials and of utilizing the grease, nitrogenous and mineral substances contained therein, and advocated the latter as the rational and proper method of dealing with them. He explained that the garbage of several cities in the United States was successfully utilized, instancing Detroit, Cincinnati and St. Louis as examples, and gave an account of some experiments in this direction on the large scale, which he had of late been conducting at the works of the Baugh & Sons Company, Philadelphia. He exhibited a number of specimens of the products obtained, and affirmed that the utilization of the large quantities of city garbage now practically wasted was attended with no serious technical difficulties, and could be made commercially profitable.

Mr. E. G. Acheson, of Monongahela City, Pa., read a paper on "Carborundum: Its History, Manufacture and Uses," illustrating the subject by the exhibition of specimens of the product, and of various forms of cutting wheels made therefrom. (Referred for publication.)

Mr. W. N. Jennings presented a number of lantern slides of local interest, which were well received.

The Secretary exhibited a reproduction of an ancient clock, styled the "Columbus Clock," affirmed to be an exact reproduction of the timekeepers in vogue at the close of the fifteenth century. The instrument was exhibited on behalf of the Bostwick & Burgess Manufacturing Company, Norwalk, O.

Under new business, the subject of the proposed amendments to the Institute's by-laws, increasing the annual dues of members and the fee for life membership, was brought forward. A motion was made and carried to proceed with the publication of the proposed amendments and postpone consideration and action thereon until the next stated meeting.

Adjourned. WM. H. WAHL, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXVI. AUGUST, 1893. No. 2

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA.*

By NIKOLA TESLA.

[*Continued from p. 19.*]

It is desirable, in order to maintain the vibration economically, to reduce the impact and frictional losses as much as possible. As regards the latter, which in the electrical analogue correspond to the losses due to the resistance of the circuits, it is impossible to obviate them entirely, but they can be reduced to a minimum by a proper selection of the dimensions of the circuits and by the employment of thin conductors in the form of strands. But the loss of energy caused by the first breaking through of the dielectric—which

* A lecture delivered before the Franklin Institute, at Philadelphia, February 24, 1893, and before the National Electric Light Association, at St. Louis, March 1, 1893.

in the above example corresponds to the violent knock of the bottom against the inelastic stop—would be more important to overcome. At the moment of the breaking through, the air space has a very high resistance, which is probably reduced to a very small value when the current has reached some strength, and the space is brought to a high temperature. It would materially diminish the loss of energy, if the space were always kept at an extremely high temperature, but then there would be no disruptive break. By warming the space moderately by means of a lamp or otherwise, the economy, as far as the arc is concerned, is sensibly increased. But the magnet or other interrupting device does not diminish the loss in the arc. Likewise, a jet of air only facilitates the carrying off of the energy. Air, or a gas in general, behaves curiously in this respect.

When two bodies, charged to a very high potential, discharge disruptively through an air space, any amount of energy may be carried off by the air. This energy is evidently dissipated by bodily carriers, in impact and collisional losses of the molecules. The exchange of the molecules in the space occurs with inconceivable rapidity. When a powerful discharge takes place between two electrodes, they may remain entirely cool, and yet the loss in the air may represent any amount of energy. It is quite practicable, with very great potential differences in the gap, to dissipate several horse-power in the arc of the discharge without even noticing a small increase in the temperature of the electrodes. All the frictional losses occur then practically in the air. If the exchange of the air molecules is prevented, as by enclosing the air hermetically, the gas inside of the vessel is brought quickly to a high temperature, even with a very small discharge. It is difficult to estimate how much of the energy is lost in sound waves, audible or not, in a powerful discharge. When the currents through the gap are large, the electrodes may become rapidly heated, but this is not a reliable measure of the energy wasted in the arc, as the loss through the gap itself may be comparatively small. The air, or a gas in general, is, at ordinary pressures at least, clearly not the best medium through

which a disruptive discharge should occur. Air or other gas under great pressure is of course a much more suitable medium for the discharge gap. I have carried on long-continued experiments in this direction, unfortunately less practicable on account of the difficulties and expense in getting air under great pressure. But whether the medium in the discharge space be solid or liquid, the same losses take place, though they are generally smaller, for just as soon as the arc is established, the solid or liquid is volatilized. Indeed, there is no body known which would not be disintegrated by the arc, and it is an open question among scientific men, whether an arc discharge could occur at all in the air itself without the particles of the electrodes being torn off. When the current through the gap is very small and the arc very long, I believe that a relatively considerable amount of heat is taken up in the disintegration of the electrodes, which partially on this account may remain quite cold.

The ideal medium for a discharge gap should only *crack*, and the ideal electrode should be of some material which cannot be disintegrated. With small currents through the gap it is best to employ aluminum, but not when the currents are large. The disruptive break in the air, or in any ordinary medium, is not of the nature of a crack, but it is rather comparable to the piercing of innumerable bullets through a mass offering great frictional resistance to the motion of the bullets, thus involving considerable loss of energy. A medium which would merely crack when strained electrostatically—and this possibly might be the case with a perfect vacuum; that is, in pure ether—would involve a very small loss in the gap, so small as to be entirely negligible, at least theoretically, because a crack may be produced by an infinitely small displacement. In exhausting, with the greatest care, an oblong bulb provided with two aluminum terminals, I have succeeded in producing so high a vacuum that the secondary discharge of a disruptive discharge coil would break through disruptively through the bulb in the form of fine spark streams. The curious point was that the discharge would completely

ignore the terminals and start far behind the two aluminum plates which served as electrodes. This extraordinarily high vacuum could only be maintained for a very short time.

To return to the ideal medium, think, for the sake of illustration, of a piece of glass or similar body clamped in a vise, and the latter tightened more and more. At a certain point a minute increase of the pressure will cause the glass to crack. The loss of energy involved in splitting the glass may be practically nothing, for though the force is great, the displacement need be but extremely small. Now imagine that the glass possesses the property of perfectly closing the crack upon a minute diminution of the pressure. This is the way the dielectric in the discharge space should behave. But inasmuch as there would be always some loss in the gap, the medium which should be continuous should exchange through the gap at a rapid rate.

In the preceding example, the glass being perfectly closed, it would mean that the dielectric in the discharge space possesses a great insulating power; the glass being cracked, it would signify that the medium in the space is a good conductor. The dielectric should vary enormously in resistance by minute variations of the E. M. F. across the discharge space. This condition is attained, but in an extremely imperfect manner, by warming the air space to a certain critical temperature, dependent on the E. M. F. across the gap, or by otherwise impairing the insulating power of the air. But as a matter of fact the air never breaks down *disruptively*, if this term be rigorously interpreted, for before the sudden rush of the current occurs, there is always a weak current preceding it, which rises first gradually and then with comparative suddenness. That is the reason why the rate of change is very much greater when glass, for instance, is broken through, than when the break takes place through an air space of equivalent dielectric strength. As a medium for the discharge space a solid, or even a liquid would be preferable. It is somewhat difficult to conceive of a solid body which

would possess the property of closing instantly after it has been cracked. But a liquid, especially under great pressure, behaves practically like a solid, while it possesses the property of closing the crack. Hence it was thought that a liquid insulator might be more suitable as a dielectric than air. Following out this idea, a number of different forms of dischargers, in which a variety of such insulators, sometimes under great pressure, were employed, have been tried. It is thought sufficient to dwell in a few words upon one of the forms experimented upon. One of these dischargers is illustrated in *Figs. 4a* and *4b*.

A hollow metal pulley P, (*Fig. 4a*,) was fastened upon an arbor a, which by a suitable means was rotated at a considerable speed. In the inside of the pulley, but disconnected from the same, was supported a thin disc h_1 (which is

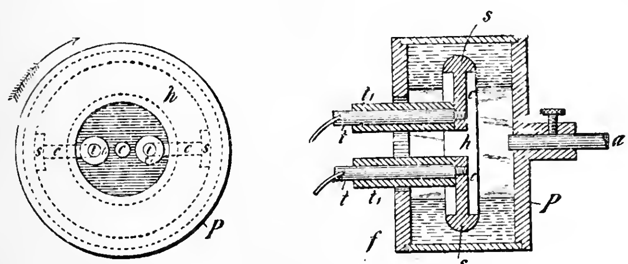


Fig. 4 b *Fig. 4 a*

Form of discharger with liquid interrupter.

shown thick for the sake of clearness) of hard rubber, in which there were embedded two metal segments s s, with metallic extensions e e, into which were screwed conducting terminals t t, covered with thick tubes of hard rubber t t. The rubber disc h, with its metallic segments s s, was finished in a lathe, and its entire surface highly polished so as to offer the smallest possible frictional resistance to motion through a fluid. In the hollow of the pulley an insulating liquid, such as a thin oil, was poured so as to reach very nearly to the opening left in the flange f, which was screwed tightly on the front side of the pulley. The terminals t t were connected to the opposite coatings of a battery of condensers so that the discharge occurred through the liquid. When the pulley was rotated the liquid was forced against the rim of the pulley and con-

siderable fluid pressure resulted. In this simple way the discharge gap was filled with a medium which behaved practically like a solid, which possessed the quality of closing instantly upon the occurrence of the break, and which moreover was circulating through the gap at a rapid rate.

Very powerful effects were produced by dischargers of this kind with liquid interrupters, of which a number of different forms were made. It was found, as expected, that a longer spark for a given length of wire was obtainable in this way than by using air as an interrupting device. In the form of discharger described, the speed, and, therefore, also the fluid pressure, were limited by reason of the fluid friction, but the practically obtainable speed was more than sufficient to produce a number of breaks suitable for the circuits ordinarily used. In some instances the metal pulley *P*, was provided with a few projections inwardly, and a definite number of breaks was then produced which could be computed from the speed of rotation of the pulley. Experiments were also carried on with liquids of different insulating powers, with the view of reducing the loss in the arc. When an insulating liquid is moderately warmed the loss in the arc is diminished.

A point of some importance was noted in experiments with various dischargers of this kind. It was found, for instance, that, whereas the conditions maintained in these forms were favorable for the production of a great spark length, the current so obtained were not best suited to the production of light effects. Experience undoubtedly has shown, that for such purpose a harmonic rise and fall of the potential is preferable. Whether it be that a solid is rendered incandescent, or phosphorescent, or that energy is transmitted by the condenser coating through the glass, it is certain that a harmonically rising and falling potential produces less destructive action, and that the vacuum is more permanently maintained. This would be easily explained if it were ascertained that the process going on in an exhausted vessel is of an electrolytic nature.

In the diagrammatical sketch, *Fig. 1*, which has already

been referred to, the cases which are most likely to be met with in practice are illustrated. One has at his disposal either direct or alternating currents from a supply station. It is convenient for an experimenter in an isolated laboratory, to employ a machine *G*, such as illustrated, capable of giving both kinds of currents. In such case it is also preferable to use a machine with multiple circuits, as in many experiments it is useful and convenient to have at one's disposal currents of different phases. In the sketch, *D* represents the direct, and *A*, the alternating circuit. In each of these, three branch circuits are shown, all of which are provided with double line switches, *s s s s s s*. Consider first, the direct current conversion; *1a* represents the simplest case. If the E. M. F. of the generator is sufficient to break through a small air space, at least when the latter is warmed or otherwise rendered poorly insulating, there is no difficulty in maintaining a vibration with fair economy by judicious adjustment of the capacity, self-induction and resistance of the circuit *L* containing the devices *l l m*. The magnet *N S*, in this case, can advantageously be combined with the air space. The discharger *d d*, with the magnet, may be placed either way, as indicated by the full, or by the dotted, lines. The circuit *1a* with the connections and devices is supposed to possess dimensions such as are suitable for the maintenance of a vibration. But usually the E. M. F. on the circuit or branch *1a* will be something like 100 volts or so, and in this case it is not sufficient to break through the gap. Many different means may be used to remedy this by raising the E. M. F. across the gap. The simplest is probably to insert a large self-induction coil in series with the circuit *L*. When the arc is established, as by the discharger illustrated in *Fig. 2*, the magnet blows the arc out the instant it is formed. Now the extra current of the break, being of high E. M. F., breaks through the gap, and a path of low resistance for the dynamo current being again provided, there is a sudden rush of the current from the dynamo upon the weakening or subsidence of the extra current. This process is repeated in rapid succession, and in this manner I have maintained

oscillation with as low as fifty volts, or even less, across the gap. But conversion on this plan is not to be recommended on account of the too heavy currents through the gap and consequent heating of the electrodes; besides, the frequencies obtained in this way are low, owing to the high self-induction necessarily associated with the circuit. It is very desirable to have the E. M. F. as high as possible, firstly, in order to increase the economy of the conversion; and, secondly, to obtain high frequencies. The difference of potential in this electric oscillation is, of course, the equivalent of the stretching force in the mechanical vibration of the spring. To obtain very rapid vibration in a circuit of some inertia, a great stretching force or difference of potential is necessary. Incidentally, when the E. M. F. is very great, the condenser which is usually employed in connection with the circuit need have but a small capacity, and many other advantages are gained. With a view of raising the E. M. F. to a many times greater value than that obtainable from ordinary distribution circuits, a rotating transformer *g* is used, as indicated in *Fig. 2a*, or else a separate high potential machine is driven by means of a motor operated from the generator *G*. The latter plan is in fact preferable, as changes are more easily made. The connections from the high tension winding are quite similar to those in branch *1a*, with the exception that a condenser *C*, which should be adjustable, is connected to the high tension circuit. Usually, also, an adjustable self-induction coil in series with the circuit has been employed in these experiments. When the tension of the currents is very high the magnet ordinarily used in connection with the discharger is of comparatively small value, as it is quite easy to adjust the dimensions of the circuit so that oscillation is maintained.

The employment of a steady E. M. F. in the high frequency conversion affords some advantages over the employment of alternating E. M. F., as the adjustments are much simpler and the action can be more easily controlled. But unfortunately one is limited by the obtainable potential difference. The windings also break down easily in consequence of the sparks which form between the sections of the armature

or commutator when a vigorous oscillation takes place. Besides, these transformers are expensive to build. It has been found by experience that it is best to follow the plan illustrated in *Fig. 3a*. In this arrangement a rotating transformer *g* is employed to convert the low tension direct currents into low frequency alternating currents, preferably also of small tension. The tension of the currents is then raised in a stationary transformer *T*. The secondary *S* of this transformer is connected to an adjustable condenser *C*, which discharges through the gap or discharger *d d*, placed in either of the ways indicated, through the primary *P* of a disruptive discharge coil, the high frequency currents being obtained from the secondary *S* of this coil, as described on previous occasions. This will undoubtedly be found the cheapest and most convenient way of converting direct currents.

The three branches of the circuit *A*, represent the usual cases met in practice when alternating currents are converted. In *Fig. 1b*, a condenser *C*, generally of large capacity, is connected to the circuit *L*, containing the devices *l l m m*. The devices *m m* are supposed to be of high self-induction so as to bring the frequency of the circuit more or less to that of the dynamo. In this instance the discharger *d d* should best have a number of makes and breaks per second equal to twice the frequency of the dynamo. If not so, then it should have at least a number equal to a multiple or even a fraction of the dynamo frequency. It should be observed, referring to *1b*, that the conversion to a high potential is also affected when the discharger *d d*, which is shown in the sketch, is omitted. But the effects which are produced by currents which rise instantly to high values, as in a disruptive discharge, are entirely different from those produced by dynamo currents which rise and fall harmonically. So, for instance, there might be, in a given case, a number of makes and breaks at *d d*, equal to just twice the frequency of the dynamo, or in other words there may be the same number of fundamental oscillations as would be produced without the discharge gap, and there might even not be any quicker superimposed vibration; yet

the differences of potential at the various points of the circuit, the impedence and other phenomena, dependent upon the rate of change, will bear no similarity in the two cases. Thus, when working with currents discharging disruptively, the element chiefly to be considered, is not the frequency, as a student might be apt to believe, but the rate of change per unit of time. With low frequencies, in a certain measure, the same effects may be obtained as with high frequencies, provided the rate of change is sufficiently great. So, if a low frequency current is raised to a potential of (say) 75,000 volts and the high tension current passed through a series of high resistance lamp filaments, the importance of the rarefied gas surrounding the filament is clearly noted, as will be seen later; or, if a low frequency current of several thousand ampères is passed through a metal bar, striking phenomena of impedence are observed, just as with currents of high frequencies. But it is, of course, evident that with low frequency currents, it is impossible to obtain such rates of change per unit of time as with high frequencies, hence the effects produced by the latter are much more prominent. It was deemed advisable to make the preceding remarks, inasmuch as many more recently described effects have been unwittingly identified with high frequencies. Frequency alone in reality does not mean anything, except when an undisturbed harmonic oscillation is considered.

In the branch *3b*, a similar disposition as in *1b*, is illustrated, with the difference that the currents discharging through the gap *d d* are used to induce currents in the secondary *S* of a transformer *T*. In such case the secondary should be provided with an adjustable condenser for the purpose of tuning it to the primary.

Fig. 2b illustrates a plan of alternate current high frequency conversion which is most frequently used and which is found to be most convenient. This plan has been dwelt upon in detail on previous occasions and need not be described here.

Some of these results were obtained by the use of a high frequency alternator. A description of such machines will

be found in my original paper before the American Institute of Electrical Engineers, and in the periodicals of that period, notably in *The Electrical Engineer*, of March 18, 1891.

I will now proceed with the experiments:

On Phenomena produced by Electrostatic Force.—The first class of effects I intend to show you, are effects produced by electrostatic force. It is the force which governs the motion of the atoms, which causes them to collide and develop the life-sustaining energy of heat and light, and which causes them to aggregate in an infinite variety of ways, according to nature's fanciful designs, and to form all these wondrous structures we perceive around us; it is, in fact, if our present views be true, the most important force in nature for us to consider. As the term *electrostatic* might imply a steady electric condition, it should be remarked, that in these experiments the force is not constant, but varies at a rate which may be considered moderate, about 1,000,000 times a second, or thereabouts. This enables me to produce many effects which are not producible with an unvarying force.

When two conducting bodies are insulated and electrified, we say that an electrostatic force is acting between them. This force manifests itself in attractions, repulsions and stresses in the bodies and in the space or medium without. So great may be the strain exerted in the air, or whatever separates the two conducting bodies, that it may break down, and we observe sparks or bundles of light, or streamers, as they are called. These streamers form abundantly when the force through the air is rapidly varying. I will illustrate this action of electrostatic force in a novel experiment in which I will employ the induction coil before referred to. The coil is contained in a trough filled with oil, and placed under the table. The two ends of the secondary wire pass through the two thick columns of hard rubber, which protrude to some height above the table. It is necessary to insulate heavily the ends or terminals of the secondary with hard rubber, because even dry wood is by far too poor an insulator for these currents of enormous potential differences. On one of the terminals of the coil, I have placed

a large sphere of sheet brass, which is connected to a larger insulated brass plate, in order to enable me to perform the experiments under conditions, which, as you will see, are more suitable for this experiment. I now set the coil to work and approach the free terminal with a metallic object held in my hand; this, simply to avoid burns. As I approach the metallic object to a distance of eight or ten inches, a torrent of furious sparks breaks forth from the end of the secondary wire, which passes through the rubber column. The sparks cease when the metal in my hand touches the wire. My arm is now traversed by a powerful electric current, vibrating at about the rate of 1,000,000 times a second. All around me the electrostatic force makes itself felt, and the air molecules and particles of dust flying about are acted upon and are hammering violently against my body. So great is this agitation of the particles, that when the lights are turned out you may see streams of feeble light appear on some parts of my body. When such a streamer breaks out on any part of the body, it produces a sensation like the pricking of a needle. Were the potentials sufficiently high and the frequency of the vibration rather low, the skin would probably be ruptured under the tremendous strain, and the blood would rush out with great force in the form of fine spray, or jet, so thin as to be invisible, just as oil will when placed on the positive terminal of a Holtz machine. This breaking through of the skin, though it may seem impossible at first, would perhaps occur, by reason of the tissues under the skin being incomparably better conducting. This, at least, appears plausible, judging from some observations.

I can make these streams of light visible to all, by touching with the metallic object one of the terminals as before, and approaching my free hand to the brass sphere, which is connected to the second terminal of the coil. As the hand is approached, the air between it and the sphere, or in the immediate neighborhood, is more violently agitated and you see streams of light now break forth from my finger tips and from the whole hand (*Fig. 5*). Were I to approach the hand closer, powerful sparks would jump from the brass

sphere to my hand, which might be injurious. The streamers offer no particular inconvenience, except that in the ends of the finger tips a burning sensation is felt. They should not be confounded with those produced by an influence machine, because, in many respects, they behave differently. I have attached the brass sphere and plate to one of the terminals in order to prevent the formation of visible streamers on that terminal, also, in order to prevent sparks from jumping to a considerable distance. Besides, the attachment is favorable for the working of the coil.

The streams of light, which you have observed issuing from my hand, are due to a potential of about 200,000 volts, alternating in rather irregular intervals, something like 1,000,000 times a second. A vibration of the same amplitude,

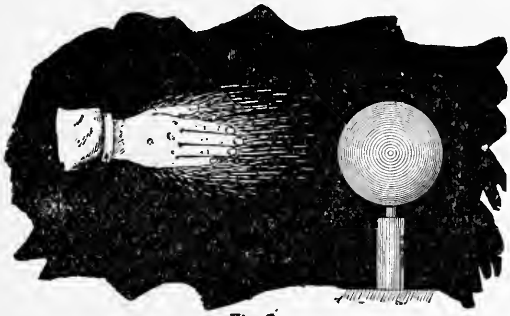


Fig. 5

Illustrating the effect of varying electrostatic force with a transformer of 200,000 volts pressure.

but four times as fast to maintain which, over 3,000,000 volts would be required, would be more than sufficient to envelop my body in a complete sheet of flame. But this flame would not burn me up; quite the reverse, the probability is that I would not be injured in the least. Yet a hundredth part of that energy, otherwise directed, would be amply sufficient to kill a person.

The amount of energy which may thus be passed into the body of a person depends on the frequency and potential of the currents, and by making both of these very great, a vast amount of energy may be passed into the body without causing any discomfort, except perhaps, in the arm, which is traversed by a true conduction current. The reason why no pain in the body is felt, and no injurious effect

noted, is, that everywhere, if a current be imagined to flow through the body, the direction of its flow would be at right angles to the surface; hence the body of the experimenter offers an enormous section to the current, and the density is very small, with the exception of the arm, perhaps, where the density may be considerable. But if only a small fraction of that energy would be applied in such a way that a current would traverse the body in the same manner as a low frequency current, a shock would be received which might be fatal. A direct or low frequency alternating current is fatal, I think, principally because its distribution through the body is not uniform, as it must divide itself in minute streamlets of great density, whereby some organs are vitally injured. That such a process occurs I have not the least doubt, though no evidence might apparently exist, or be found upon examination. The surest to injure and destroy life, is a continuous current, but the most painful is an alternating current of very low frequency. The expression of these views, which are the result of long-continued experiment and observation, both with steady and varying currents, is elicited by the interest which is at present taken in this subject, and by the manifestly erroneous ideas which are daily propounded in the journals.

I may illustrate an effect of the electrostatic force by another striking experiment, but before, I must call your attention to one or two facts. I have said before, that when the medium between two oppositely electrified bodies is strained beyond a certain limit, it gives way, and, stated in popular language, the opposite electric charges unite and neutralize each other. This breaking down of the medium occurs principally when the force acting between the bodies is steady, or varies at a moderate rate. Were the variation sufficiently rapid, such a destructive break would not occur, no matter how great the force, for all the energy would be spent in radiation, convection and mechanical and chemical action. Thus the *spark* length, or greatest distance through which a *spark* will jump between the electrified bodies is the smaller, the greater the variation or time rate of change. But this rule may be taken to be true only in a

general way, when comparing rates which are widely different.

I will show you by an experiment the difference in the effect produced by a rapidly varying, and a steady or moderately varying force. I have here two large circular brass plates *p p* (*Figs. 6a* and *6b*), supported on movable insulating stands on the table, and connected to the ends of the secondary of a similar coil as the one used before. I place the plates ten or twelve inches apart and set the coil to work. You see the whole space between the plates, nearly two cubic feet, filled with uniform light, *Fig. 6a*. This light is due to the streamers you have seen in the first experiment, which are now much more intense. I have already pointed out the importance of these streamers in commercial apparatus and their still greater importance in some

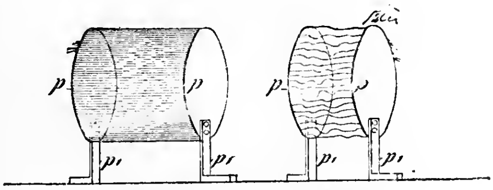


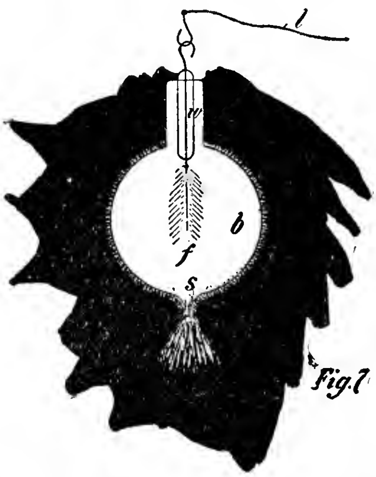
Fig. 6a *Fig. 6b*

Illustrating the effects of rapidly varying and steady electrostatic force.

purely scientific investigations. Often they are too weak to be visible, but they always exist, consuming energy and modifying the action of the apparatus. When intense, as they are at present, they produce ozone in great quantity, and also, as Professor Crookes has pointed out, nitrous acid. So quick is the chemical action, that if a coil such as this one, is worked for a very long time it will make the atmosphere of a small room unbearable, for the eyes and throat are attacked. But when moderately produced, the streamers refresh the atmosphere wonderfully, like a thunder storm, and exercise unquestionably a wholesome effect.

In this experiment the force acting between the plates changes in intensity and direction at a very rapid rate. I will now make the rate of change per unit time much smaller. This I effect by rendering the discharges through the primary of the induction coil less frequent, and also by

diminishing the rapidity of the vibration in the secondary. The former result is conveniently secured by lowering the E. M. F. over the air gap in the primary circuit; the latter, by approaching the two brass plates to a distance of about three or four inches. When the coil is set to work you see no streamers or light between the plates, yet the medium between them is under a tremendous strain. I still further augment the strain by raising the E. M. F. in the primary circuit, and soon you see the air give way and the hall is illuminated by a shower of brilliant and noisy sparks, *Fig. 6b.* These sparks could be produced also with unvarying force; they have been for many years a familiar phenomenon, though they were usually obtained from entirely different



Breaking a bulb on open circuit.

apparatus. In describing these two phenomena, so radically different in appearance, I have advisedly spoken of a "force" acting between the plates. It would be in accordance with accepted views to say that there was an "alternating E. M. F." acting between the plates. This term is quite proper and applicable in all cases where there is evidence of at least a possibility of an essential interdependence of the electric state of the plates, or electric action in their neighborhood. But whether the plates be removed to an infinite distance, or to a finite distance, there is no probability or necessity whatever for such dependence. I prefer to use the term "electrostatic force," and to say that such a force is acting around each plate or electrified

insulated body in general. There is an inconvenience in using this expression as the term incidentally means a steady electric condition; but a proper nomenclature will eventually settle this difficulty.

I now return to the experiment to which I have already alluded, and with which I desire to illustrate a striking effect produced by a rapidly varying electrostatic force. I attach to the end of the wire *l* (*Fig. 7*), which is in connection with one of the terminals of the secondary of the induction coil, an exhausted bulb *b*. This bulb contains a thin carbon filament *f*, which is fastened to a platinum wire *w*, sealed in the glass and leading outside of the bulb, where it connects to the wire *l*. The bulb may be exhausted to any degree attainable with ordinary apparatus. Just a moment before, you have witnessed the breaking down of the air between the charged brass plates. You know that a plate of glass, or any other insulating material, would break down in like manner. Had I therefore a metallic coating attached to the outside of the bulb, or placed near the same, and were this coating connected to the other terminal of the coil, you would be prepared to see the glass give way if the strain were sufficiently increased. Even were the coating not connected to the other terminal, but to an insulated plate, still, if you have followed recent developments, you would naturally expect a rupture of the glass.

But it will certainly surprise you to note that under the action of the varying electrostatic force, the glass gives way when all other bodies are removed from the bulb. In fact, all the surrounding bodies we perceive might be removed to an infinite distance without affecting the result in the slightest. When the coil is set to work, the glass is invariably broken through at the seal, or other narrow channel, and the vacuum is quickly impaired. Such a damaging break would not occur with a steady force, even if the same were many times greater. The break is due to the agitation of the molecules of the gas within the bulb, and outside of the same. This agitation, which is generally most violent in the narrow pointed channel near the seal, causes a heating and rupture of the glass. This rupture would, how-

ever, not occur, not even with a varying force, if the medium filling the inside of the bulb, and that surrounding it, were perfectly homogeneous. The break occurs much more quickly if the top of the bulb is drawn out into a fine fibre. In bulbs used with these coils such narrow, pointed channels must therefore be avoided.

[*To be continued.*]

PRESENT DEVELOPMENT OF HEAVY ORDNANCE IN THE UNITED STATES.

BY W. H. JAQUES, Ordnance Engineer.

[*A lecture delivered before the Franklin Institute, January 6, 1893.*]

[*Concluded from p. 36.*]

Of the two systems of breech-loading in general use—the American-French interrupted screw and what is now familiary known as the Krupp wedge—the former is used by both branches of our military service.

While differing in details, the general operation is to unscrew the plug or breech screw, withdraw it, land and latch it on the tray, carrier or bracket (as this part is variously called), swing the tray on its hinge pin to one side and catch and hold it there during the operation of inserting the projectile and powder charge.

This view* shows the mechanism used by the Navy for the ten-inch and twelve-inch guns, when closed.

This view* the same when the breech is open.

The apparatus* employed by the Army is composed of a greater number of parts and is more complicated; but it works well and has a peculiar double-threaded shaft, by which increased power and speed are obtained for operating the breech-block.

---

* Lantern view.

Of the many hundreds of devices that have been proposed for the closing and gas-checking of breech-loading ordnance, the most effective at the present time are the Canet-Whitworth breech mechanisms, *Figs. 2* and *3*, and the de Bange gas check. Their chief advantages are strength, simplicity,

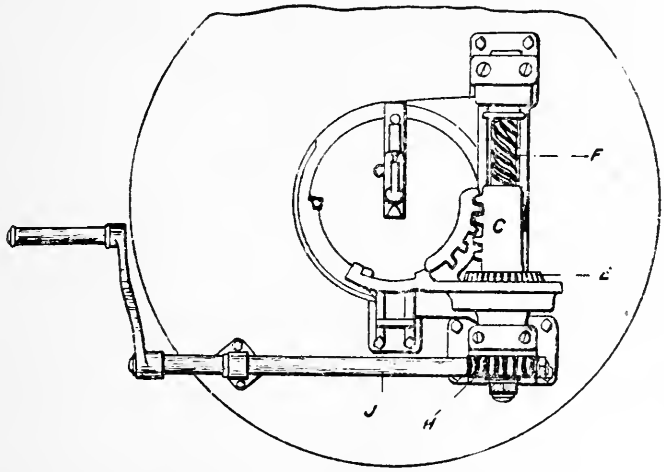


FIG. 2.

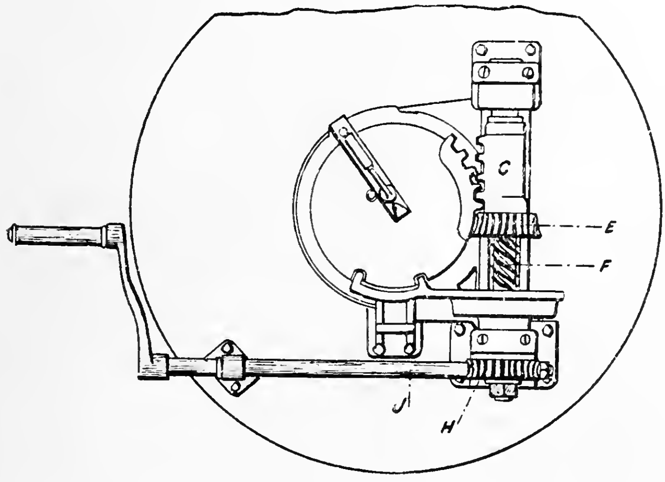


FIG. 3.

Canet-Whitworth breech-mechanism.

effective gas-checking and positive discharge of cartridge case when employing fixed ammunition. The lighter ones, although applicable to the heavier guns, are employed principally for rapid fire guns.

For calibres up to and including eight-inch, the breech plug is disengaged and withdrawn by a simple rotary single

movement of a lever in a horizontal direction and again entered and engaged by a similar movement in the reverse direction.

For the heavier guns, where hand power is employed instead of pneumatic or hydraulic power, the breech plug, carrier or tray and fittings are controlled, disengaged and withdrawn by a continuous rotation of a crank in one direction and the reverse movement governed by a similar rotation in the opposite direction.

The re-cocking is performed by levers and sliding bars during the operation of opening the breech and safety guards are automatically adjusted in the closing, which prevents any possibility of the gun being fired before the breech is perfectly closed. Spring catches are fitted to control the motion of the various parts while the breech is open.

In the Canet system when the shaft *J* (*Fig. 3*) is rotated, motion is communicated through a worm at its end to the worm-wheel *H*, which is fitted and gives motion to the screw-shaft *F* supported at its extremities by suitable bearings screwed to the breech of the gun. The collar *C* and toothed-wheel *E*, prevented from rotating by a projection working in a groove in the tray, move along the screw-shaft *F*, rotating the breech plug until it is disengaged from the interrupted screw threads in the breech of the gun, when their translatory movement being stopped they are released and the wheel is left free to engage the screw thread of the breech plug, and by its revolution withdraw the block or plug from the breech, landing and locking it upon the tray which is then swung upon its axis to, and locked in, the loading position. To close the breech the operations just described are reversed (*Fig. 2*). All of these operations are done by a continuous rotation in the direction requisite for opening or closing the breech.

The de Bange gas check* proper is a plastic ring composed of sixty-five per cent. of amianthus (an earth or mountain flax, similar to asbestos) and thirty-five per cent.

* Lantern view.

of tallow, contained in a canvas covering. It fits snugly around the mushroom-shaped stem which is inserted in the axis of the breech block. Zinc, copper or steel discs protect the plastic pad and keep it within its proper limits. The asbestos, being a mineral, and not combustible, retains the tallow and prevents the mixture from becoming fluid. The tallow

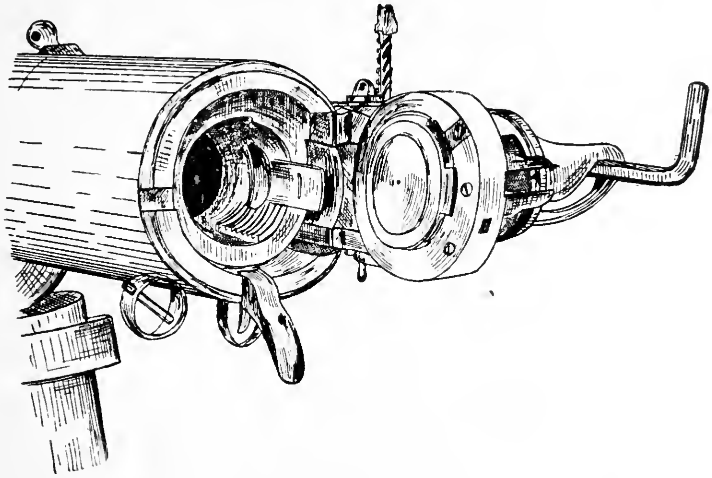


FIG. 4.

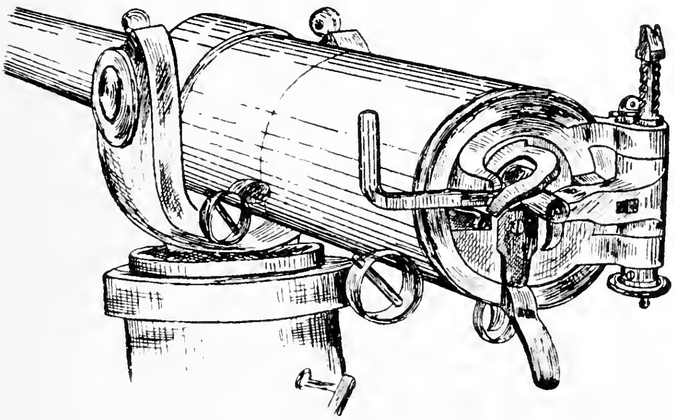


FIG. 5.

Seabury breech-mechanism.

being soft and greasy, yields easily to the pressure and takes the form of its casing; oozing slightly through the canvas cover it acts also as a lubricant.

When the gun is fired, the pressure upon the movable head is transmitted to the gas check, which is forced against the side of the chamber, effecting perfect obturation.

Although *not* the case in all constructions and particularly in the French, the breech screw or plug should engage in the jacket and not in the tube.

Canet suggests that the thread be interrupted by cutting away helical* segments instead of straight longitudinal ones, which is the usual method. This would make the mechanism not quite so simple to manufacture as the other, but its advantages may compensate for that since the thrust is more uniformly distributed over the screwed portion of the jacket. I know, however, of no accident ever having occurred which was due to the usual type of interrupted screw.

Two American breech mechanisms, that are receiving attention abroad as well as at home, are the Seabury and Gerdon. Both may be applied to the heavy calibres.

Figs. 4 and *5*, showing the breech open and closed, were taken from a six pounder rapid fire gun fitted with the Seabury mechanism, now at the Sandy Hook Proving Ground awaiting test. The calibre is fifty-seven millimetres, the same size as the Hotchkiss and Driggs-Schroeder two-and-one-fourth-inch service guns. The mechanism works with the utmost ease and gives assurances of being successfully applied not only to the 3·2-inch field guns, now in use in the Army, and to the four-inch rapid fire arm but to still larger calibres.

Although there is no necessary limit in its application to either large or small calibres, for guns of five inches and upwards, *this* design, *Figs. 6* and 7, will probably be preferred, gearing being substituted for the hand lever in the largest sizes.

The Gerdon system of breech mechanism, *Figs. 8, 9* and *10*, is a combination of the interrupted screw with the sliding wedge, or a contrivance composed of what Mr. Gerdon considers the best elements of those two well-known and prolifically modified devices. He claims to reduce the three motions of rotation and translation of the French system to one of each retaining the superior de Bange gas check; but

* Lantern view.

as these three motions have been converted into a continuous one in the Canet and Seabury systems, the test of the Gerdon device that is now being made in a field gun may

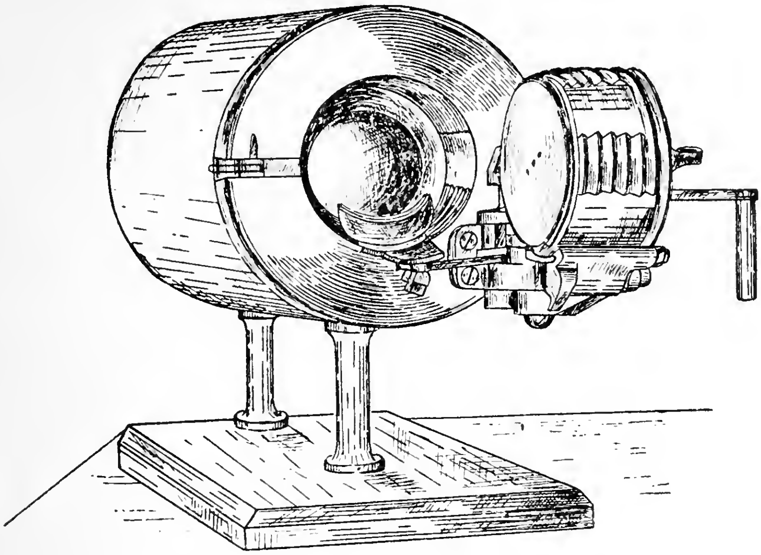


FIG. 6.

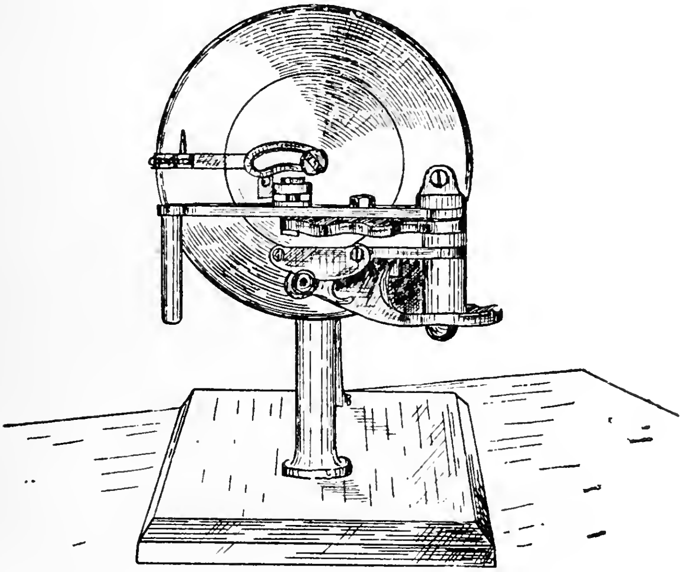


FIG. 7.

Seabury breech-mechanism.

not prove the combination to be as simple and effective as the latest designs of the French type.

A variety of materials has been proposed and advocated for heavy gun construction, but *steel* advocated by Whit-

worth and Krupp as early as 1860 and still employed by them has vanquished all others in the race and seems likely to be retained for as long a period to come.

Armstrong accepted steel and breech loading with other early advocates but abandoned the steel barrel in 1861 as being untrustworthy and difficult to produce; and substituted the very justly criticised wrought-iron coil. Although Armstrong was knighted for this wrought-iron coil breech

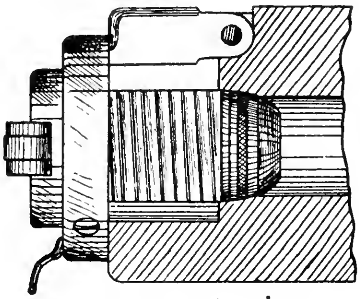


FIG. 8.

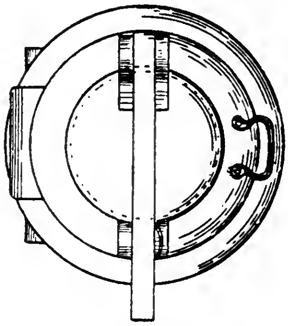


FIG. 9.

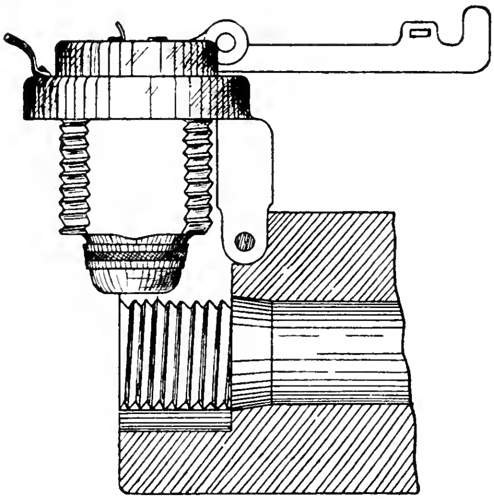


FIG. 10.

Gerdon breech-mechanism.

loader it was soon abandoned for a return to muzzle loading. The coil which ought never to have been accepted was retained while that feature which was a marked advance in artillery—breech loading—was abandoned.

Captain Eardley-Wilmot considers this was not a retrograde step at the time when guns were short and could be more conveniently loaded with simpler means, but thinks that England's fault was in returning to the system o

muzzle loading, to which she reverted, after the introduction of slow-burning powder which requires a long gun to utilize all its energy.

Whitworth and Krupp, however, stuck to steel and breech loading, and history has well endorsed and proved their foresight and judgment; and although Great Britain waited a quarter of a century before she acknowledged Whitworth's supremacy in gun-making, she has at last done so, and Mr. Gledhill's (Whitworth & Co.) type of gun and the material of which it is made stands in the front rank to-day.

Both branches of our Government use almost exclusively, for their *heavy* guns, fluid-compressed, hydraulic-forged, steel, and, as they have become assured of the soundness of the material when produced in larger masses, have decreased the number of parts of the guns; for example, those of the eight-inch gun, numbering ten in 1887, to three parts in 1892.

As the Midvale Steel Company has already delivered a considerable number of forgings for the smaller calibres of steel that has not been either fluid-compressed or hydraulic-forged, and has been awarded a contract for the heavier calibres, the United States Government's comparatively exclusive use of the water-shaped material will probably soon cease, as even as far back as 1884 comparisons of the physical characteristics of the two steels showed the uncompressed material fully equal to the required specifications.

The increasing use of nickel in steel suggests a few words concerning this element, particularly as it is about to make its debut in a large calibre service gun (a thirty-five calibre eight-inch B. L. R.), the forgings for which have been made by the Bethlehem Iron Company.

In this connection it is most seriously to be regretted that circumstances of a discouraging character should have intervened to prevent Mr. Riley from continuing the excellent metallurgical work he so happily and ably commenced in connection with the alloys of nickel and steel, for the reason that since the publication of his lecture to the Iron and Steel Institute, May 4, 1889, so many of his views have been proved by further experiment and practice.

Bethlehem's part in this work is so well known by the practical results she has obtained, the gun forgings and other products supplied and the superior resistance of her armor, that I need make no detailed statement here of our accomplishments. Further, they have already been referred to by the chiefs of the Bureaus of Steam Engineering and Ordnance in their last annual reports.

As you will no doubt recall, Riley, Dick and Packer commenced their experiments with samples of French crucible nickel steel containing three per cent., five per cent. and twenty-five per cent. of nickel; were subsequently assured by personal investigation that the desired products could be obtained with certainty, not only in the crucible but with perfect control in the open hearth, and that nearly all the nickel would be found in the steel. Riley, in the lecture referred to, described the action of the steel in the mould, its appearance, value of scrap and the care and temperatures required to work it. He made a sufficient number of tests to show the marked increase of tensile strength and elastic limit produced by certain increments of nickel without impairing the elongation or contraction of area to any noticeable extent. He pointed out the effects of a variation of the proportions of carbon and manganese with the same percentage of nickel, the point where the increment of nickel changed its hardening influence to one of softening ductilizing, its neutralizing effect upon carbon, the difficulties of machining, and crowned his report by giving due credit to the patentee, French steel makers, his assistants and the authorities.

Together with other conclusions, he said: "I am glad to be able to state that before the region of extreme difficulty of machining is reached we have qualities of nickel-steel available which will be of the utmost value for a very large number of purposes."

Comparing ordinary steel with nickel steel he adds: "I think there will be no hesitation in deciding that there will be a very great advantage gained by the use of the latter—advantage either in reduction of scantling or in increased strength and ductility.

"In the very important matter of corrodibility, it is with the greatest satisfaction I can state that the steels rich in nickel are practicably non-corrodible, and that those poor in nickel are much better than other steels in this respect. Some samples of the richer nickel-steels which have been lying exposed to the atmosphere for several weeks will show an untarnished fracture."

These experiments to test the non-corrodible qualities of the various percentages of nickel-steel, it will be remembered, were made in connection with Abel's corrosive liquid and hydrochloric acid water.

I have cited Riley's conclusions to show how accurately they have been verified by the results since obtained, which give abundant testimony of the care and faithfulness with which his experiments were made.

Mr. Hall, of Sheffield, claims to have made the first nickel-steel gun, which instrument is reported to have burst at the first round, the rupture being due to the absence of suitable transverse strength. Whether this was due to the poor steel, poor construction, or the presence of nickel was not stated.

Many other nickel-steel guns have been experimented with, but Krupp's comparative tests of two three-and-a-half-inch field guns, one made of ordinary Krupp steel, and the other of nickel steel, appear to be the first trials of much importance that have been given publicity.

Each gun was loaded with shell containing 170 grammes of picric acid, the centre of the shell in each case being 300 millimetres from the muzzle.

When the shells were exploded, the crucible steel gun burst into many pieces, while the nickel-steel gun remained entire, showing an increase of the bore of 7·4 millimetres at the site of the projectile, but no cracks anywhere.

The trial was continued with another shell containing 180 grammes of picric acid. Its explosion caused an enlargement of 9·50 millimetres and a longitudinal crack 80 millimetres long. No particle of metal was detached from the gun.

In reference to the suppy of nickel for guns, armor and

the great variety of the industrial arts, a perusal of the able report of Mr. Archibald Blue, Director of the Bureau of Mines, Ontario, will satisfy you all that the ore is to be found in abundance nearer than New Caledonia, money and plant being important requisites.

Mr. Blue has kindly sent me samples of the nickel ores of the various districts, but their delivery has been delayed by the same storm that has kept some of your members at home to-night.

I am also indebted to Mr. Robert M. Thompson and Lieutenant Cornwell, of the Orford Copper Company, of New York, for the samples before you of nickel matte and refined nickel.

In connection with gun construction, it may be interesting to you to recall some of the earlier breech-loading guns, in order that you may recognize the progress that has been made. The original Armstrong gun* contains practically nothing that has been retained, while the Whitworth gun* here shown, made in four parts, contains, with the exception of the mechanical shape of its bore, much that is in use to-day; it was made of steel, of few parts, and had great strength and high power. It is true it is a later design than the original Armstrong gun, but the earliest Whitworth guns were made of steel, were strong, and had a very efficient wedge* for closing the breech.

Passing from the Armstrong gun of 1861 to another of that famous establishment's productions thirty years later, we have before us the 110-ton breech-loading rifle* which, with 960 pounds of brown prismatic powder, costing $400, discharges a steel projectile weighing 1,800 pounds, valued at $600; muzzle velocity, 2,087 foot-seconds; muzzle energy, 54,390 foot-tons; penetration of wrought iron at muzzle, 34·2 inches, at 2,000 yards, 30·1 inches.

The British 110-ton guns, about which there has been so much discussion, are not only faulty in construction, but are composed of too many pieces, the chase hoops particularly being too numerous and short to be of any use in supplying

---

* Lantern view.

the longitudinal support which the long tube requires. The original design has undergone two marked changes, substituting longer hoops, but even these were not of sufficient proportions to entirely remedy the defects of the separation of the remaining short hoops on the upper side caused by the drooping of the muzzle.

The gun, even as it now exists, should not be imitated, and will not be by such gun factors as Whitworth and Bethlehem, who possess the powerful appliances requisite for shaping, treating and assembling the few heavy parts that should make up guns, even of such heavy calibres.

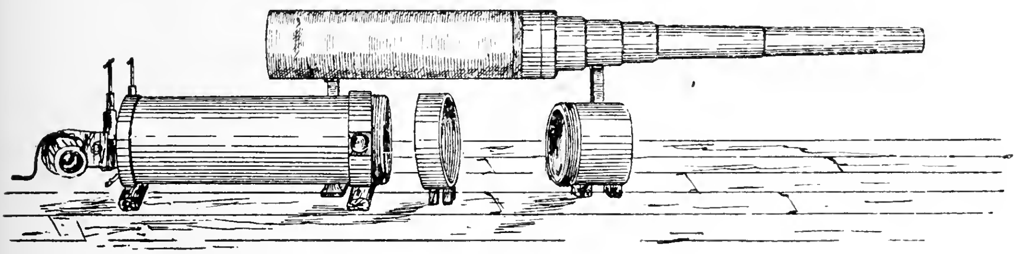


FIG. 11.

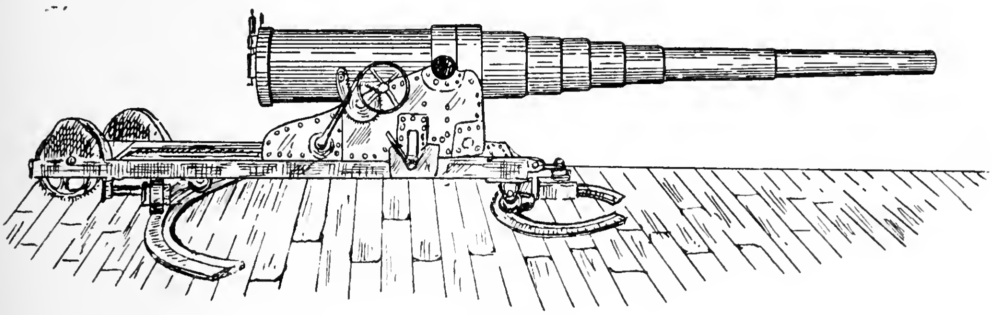


FIG. 12.
De Brynk B. L. rifle.

Whitworth's new thirty-five calibre twelve-inch, fifty-ton breech loaders for the British War Office, composed of three pieces only, are but a precursor of as simple and strong a design for the heavier calibres.

Another design, *Fig. 11*, combining few parts, simple construction, strength, separation of the transverse and longitudinal strains, in which the tube can be turned in case any portion of it becomes badly eroded, easily transported in parts, and readily taken apart if any injured parts require to be replaced, is the de Brynk gun, the suggestion of a

Russian artillery officer. A number of these guns have already been put into service.

Fig. 12 is the gun assembled.

I desire to especially emphasize the causes of the mishaps to the British 110½-ton guns, because their failure does not convey to my mind any reflection upon the usefulness of such large calibres, for it is quite as simple for the steel works I have just named to construct a sound 110-ton gun as it is for smaller establishments to make a one-pounder; and there can be no doubt that the more powerful the guns of a battleship are the more formidable an enemy she will be.

In my paper, on the "Recent Progress in the Development of War Material in the United States," read at the annual meeting of the British Iron and Steel Institute in London, in May, 1891, I referred to this question in the following words:

At the Institute's autumn meeting of 1886, Mr. Charles Markham said: "Rightly or wrongly the strong feeling generally prevailed that the manufacturer of our (British) guns was not worthy of the mechanical reputation of the country."

I deem the failures mechanical only, and if the guns are constructed in a manner equal to many of the modern marine engines that have been built in Great Britain, they will be equally efficient and serviceable.

The efficient service of these guns must not be compared directly with the number of rounds that can be fired from smaller calibres, and the weight of metal thus employed, but from the effective amount of destructive work that can be got out of them, particularly their power to demolish the hard armor of chilled iron and case-hardened steel now so successfully manufactured.

The United States is not the only nation engaged in successfully producing hard armor, nor is the method employed by Mr. Harvey, although thus far the most successful, the only one that the gun has to meet.

The general success and probable general acceptance for a period, of hard armor, would seem to emphasize the

opinion I have so often expressed that Great Britain's reduction of fifty per cent. in the maximum weight of her ordnance was too radical and not justified by the circumstances attending the failures that influenced the change.

The tendency to substitute for the larger armament an increased number of guns of reduced calibre, notably of the rapid-fire class, will no doubt soon meet with a reaction, because of the loss of that powerful element of destruction, the shattering power so necessary in combat with heavily armored ships. A mixed battery of large and small guns is no doubt the most useful compromise, for what is a ship to-day other than a compromise—in fact, a combination of compromises?

Of other systems of gun construction and other material than forged steel, recommended for trial within the last few years, may be mentioned the Woodbridge wire-wound guns* of ten-inch calibre (employing longitudinal bars and soldered wire) for the Army, and six-inch for the Navy; the Crozier ten-inch wire-wound gun (jacketed and hooped with steel castings); the five-inch Brown segmental tube wire gun;* the Haskell multicharge gun; the twelve-inch cast iron mortar, and two six-inch steel cast guns.

Three of these have been tested and failed, viz: the two steel cast guns and the twelve-inch cast-iron mortar. In December, 1888, the Bessemer steel cast gun went to pieces at the first round with a full charge, doing considerable damage to the proving ground. In February, 1889, the open-hearth steel gun was tested; the report of the trials stated that although the gun escaped rupture the test demonstrated, as calculated, that the service pressure, while less than fifteen tons to the square inch, was too great for the elastic limit of the metal and that the permanent enlargement of the bore was greater than could be admitted in a gun issued to service.

The twelve-inch cast-iron mortar* burst explosively and violently in October, 1889, at the twentieth round, and a long-fought battle for cast iron was finally decided.

---

* Lantern view.

Some of you will recall that a gun of the Woodbridge type and one of the Haskell type failed a few years ago, and although slow-burning powder has in a much simpler way supplied what the Lyman-Haskell type was designed to accomplish, Congress authorized the construction of another gun which is now being built from designs possessing a little less architectural beauty than the one* now before you, but quite as unmechanical.

For mortars, the forged built-up rifled type of steel construction is also generally accepted and greatly increased accuracy and range are obtained.

Viewed from the point of their destructive power, if successful, the pneumatic and other types designed for throwing high explosives should be embraced in this paper, but they are not yet assigned a place among high-power breech-loading rifles, although many of them have been undergoing trial for years with varying success and failure.

Bott, Chamberlain, Dudley, Ericsson, Gathmann, Giffard, Graydon, Haskell, Justin, Lässoe, Mefford, Rapieff, Reynolds, Zalinski and others have had their inventions tested more or less extensively, employing air or powder for transmitting energy to the projectile. Bott and Chamberlain, I think, are the only ones who place the motive-power in the projectile itself. It is said that Bott fills the rear of his shell with compressed air instead of introducing the air in the gun; while Chamberlain uses electricity and hydrogen in either the projectile or gun. Giffard employs liquid carbonic acid instead of powder.

Of all these types, the Ericsson-Lässoe (submarine) and Rapieff-Zalinski, with its modifications (aërial) have given the greatest promise, and will, no doubt, be introduced into general service.

Rapid-fire guns have already gone beyond their own domain and encroached upon the field of heavy ordnance, having been successfully carried to calibres a little above six inches.

To fully describe the many designs for which novelty

---

* Lantern view.

and value are claimed would require many days, and the differences between them would be of little interest to others than the inventors and patent attorneys.

In regard to the development of our industries for the supply of heavy ordnance a most satisfactory account can be rendered.

In 1886, we had practically nothing. To-day, steel for guns of any calibre can be supplied by the private steel industries of the nation, and two splendid gun factories have been built and equipped where the forgings can be quickly machined and assembled, and the guns rapidly fitted for service. These two gun factories will soon be supplemented by a third, at Bethlehem.

Not only all this has been accomplished, but from the great establishment at Bethlehem alone (built up and equipped without any financial aid from the Government), the Government has received over 300 sets of gun forgings (including those of thirteen-inch calibre) and armor-plates of ten and one-half-inch and fourteen-inch thickness, whose resistance has astonished the world; while the Navy Department and our splendid ship-yards depend almost solely upon it for shafting and other heavy forgings.

There are many to whom much credit is due for this splendid progress (and your Midvale deserves no small part of it), many spokes of the wheel that is running so smoothly and successfully now, but most credit seems due to the organization of and encouragement given by Secretaries Chandler and Lincoln to the Gun Foundry Board appointed by President Arthur in 1883. This Board, after familiarizing itself with the situation at home, gleaned from the old world all that was needed to frame recommendations adapted to our own resources and requirements. Its suggestions were so comprehensive that we find the policies of the two departments to-day encompassed by them.

This report and the subsequent legislation based thereon marked as distinct an era in the restoration of our prestige as producers of war material as the Registry Bill passed last year bids fair to record in the rehabilitation of our merchant marine.

To show the effect of modern steel projectiles, when fired at high velocities against steel plates, I have prepared the following views* of the results of the test of an eleven-and-one-half-inch Bethlehem plate.

These results, however, have been so greatly surpassed by succeeding experimental and service plates which Bethlehem has delivered to the Government, that they are presented only for the purpose of showing the value of our first production and to serve as a comparison for the greater resistance secured in our later plates. Without giving details of the many experimental and ballistic trials to which our armor has been subjected, I have cited one of a fourteen-inch nickel-steel plate,* representing battle-ship armor and that which took place at Bethlehem's Proving Ground,* July 30th last, when the ten-and-one-half-inch nickel-steel Harveyized plate so completely pulverized the five eight-inch, 250 pounds Holtzer shells fired at a striking velocity of 1,700 foot-seconds, and aggregating an energy of 25,040 foot-tons. Both plates were subjected to unusually severe tests; in fact, very much more severe than the foreign standards. Against the first a ten-inch gun was used, the projectile weighing 500 pounds, powder charge of 140 pounds, and a striking velocity of 1,410 feet a second. None of the three shots fired succeeded in getting far enough into the plate to show the backing. All three shots rebounded, one of them back to the muzzle. The deepest penetration was fourteen inches. One of the projectiles, an imported Firth, broke. The plate was perfectly uniform; there were no cracks and not even a bolt or washer started.

The results with the second,* although not comparable from the same point of view, were even more remarkable.

In the one case we have a type of resistance which will keep out a projectile of any calibre if thick enough, while in the other, a plate that will destroy the projectile until a calibre is reached whose smashing and racking energy will demolish the protection, although, perhaps, at the risk of its own destruction.

* Lantern view.

In either case the heavy calibres will be needed.

Before closing, I desire to call your attention to this view* of the comparative sizes of the guns now used by our Navy with their projectiles and powder charges, commencing with the one-pounder and finishing with the sixteen-inch, 111½-ton gun.

All but the last have been made, and Bethlehem has had the honor of supplying steel for all the calibres up to and including the thirteen-inch.

This table* contains the details of all Navy guns commencing with the four-inch, and I will leave it before you for those who are not already familiar with its contents.

Mr. Chairman, it has given me great pleasure to accept your invitation this evening to talk with you upon a subject so closely connected with the development of our Navy.

The recent legislation, offering American registration two of the fastest transatlantic steamers, is but a small link in the chain needed to restore our supremacy of the seas; but, like the Irishman who, when he had secured a place for his head in Paradise, had no fear for the rest of his body, this is the link that will not long be left alone, and I am sure that I can safely predict a very near future when our flag will fly at the peaks of a merchant fleet which will advance our commercial interests in every part of the world, and be a menace to any nation that will be unwise enough to have any serious quarrel with us.

Mr. Chairman and gentlemen, I thank you for your kind attention and know you will all join me in thanking Mr. Sawyer, for his able assistance in presenting my illustrations.

NOTE.—Mr. Jaques' paper was elaborately illustrated by a large number of appropriate lantern views, which facilitated following the writer's text.

He exhibited a six-inch Holtzer armor-piercing shell which had been fired against Bethlehem's eleven-and-one-half-inch experimental plate; it was perfect; its point as sharp as a needle; and could be used again after re-banding.

Mr. Jaques also showed his hearers samples of nickel matte from the Sudbury Mines; of refined nickel from the Orford Copper Company; and of nickel-steel armor made by the Bethlehem Iron Company.

---

* Lantern view.

THE SPECIFIC HEATS OF THE METALS.

By Jos. W. Richards, Ph.D.,
Instructor in Metallurgy, etc., in Lehigh University.

[*A lecture delivered before the Franklin Institute, January 30, 1893.*]

[*Continued from p. 53.*]

V.

The heat or energy absorbed by a substance for 1° rise of temperature is divided up in the body into several parts. One fraction of it does external work, if the substance is free to expand. The amount of this for solids and liquids is so small as to be negligible, but for gases it amounts to as much as two-fifths of the whole specific heat. As far as the metals are concerned, we can neglect it. A second fraction of the energy absorbed goes to increasing the energy of atomic motion within the molecule. For solids and liquids, where the molecule is complex, this will amount to a considerable proportion of the whole; for gases it is a much smaller fraction. The third and last part of the energy absorbed may be considered as going to increase the energy of vibration of the molecules as a whole; that is, increasing the temperature of the substance; for, on the mechanical theory of heat, the temperature of a body is measured by the energy of vibration of its molecules as a whole. We can therefore put

$$Q = \text{molecular energy} + \text{atomic energy} + \text{external work.}$$

Leaving out of the discussion the last term, we may say that the proportion which the first two terms bear to each other or to the whole has not been solved for solid and liquid bodies, but has been worked out very satisfactorily for gases, especially by Clausius and Naumann.

The most striking law which has been discovered regard-

ing specific heats is the law of Dulong and Petit, which affirms that they vary inversely as the atomic weights of the elements. The metals behave very well in this respect, the products of their atomic weights and specific heats being all nearly the same. But, in order to attain this uniformity, the metals must be compared at ordinary temperatures, since the specific heats vary so greatly. Iron, for instance, gives the usual product, about 6·3, if the specific heat at 50° is taken, but if its specific heat at 900° were taken this product would be just about double. But, the fact remains that there are slight variations in the products (atomic heats) at ordinary temperatures, and much speculation has been indulged in regarding their causes. In some instances, a great variation has been due to incorrect determinations of the specific heat, or from the specimen used not being perfectly pure. Manganese, for instance, has never been obtained perfectly free from silicon or carbon, either of which increases its specific heat; while aluminum has generally been used containing iron, which decreases its specific heat. Determinations with the chemically pure metal would give in both cases atomic heats nearer the average. Yet, allowing for this source of error, there are still variations to be explained, and the only reasons we can assign are that the metals are in different states of aggregation, requiring different amounts of work to overcome the interior cohesion of the particles or to elongate the metal. It is possible, therefore, that the differing densities, hardness and strength of the metals are the various disturbing influences which prevent their atomic heats from being exactly alike at ordinary temperatures.

Some investigators have tried to bring these facts into the calculation and take strict account of them. P. Joubin, for instance, states that for any metal the product of the specific heat and specific gravity (which would be the specific heat of unit volume) is proportional to the product of the modulus of elasticity into the [linear (?)] coëfficient of expansion by heat. H. Fritz states that the product of the atomic heat, the specific heat of unit volume and the cube root of the atomic volume is equal to the cube root

of the absolute temperature of the melting point into the specific heat of unit volume divided by 1·28; that is,

$$(\text{at. ht.}) \times (\text{sp. ht. unit vol.}) \times (\text{at. vol.})^{1/3}$$
$$= \left[\text{M. P.} \left(\frac{\text{sp. ht. unit vol}}{1 \cdot 28} \right) \right]^{1/3}$$

Fritz claims to have verified this formula for forty-eight of the elements, but I cannot offer any remarks, not having seen the original paper.

Weibe holds that the amount of heat necessary to raise an element from the absolute zero to its melting point (taking atomic weights) is inversely apportioned to its coëfficient of cubical expansion. This rule holds good for some of the elements, especially for those crystallizing in the isometric system, but there are many exceptions to it, so that is not a satisfactory solution of the problem of reconciling the differences in the atomic heats.

A rule of somewhat similar nature has been discovered by the writer, applying to the latent heats of fusion. I have found that the latent heat of fusion of the metals is frequently a simple fraction of the heat required to raise the metal from the absolute zero to its melting point. It is in many cases simply one-third. Let us illustrate by several examples, referring to the previous discussions for the data:

Tin:

	Calories.
Bède's formulæ would give for the heat from absolute zero to melting point,	27·6
One-half of this would be,	13·8
Observed by Person,	13·73
Observed by Richards,	14·56

Silver:

Pionchon gives from M. P. to 0°,	60·32
Formula suggested gives (0° to 273°),	14·45
Total heat to absolute zero,	74·77
One-third of this,	24·92
Observed by Pionchon,	24·72

Platinum :

	Calories.
Gives in cooling to 0° (Violle),	75·21
From 0° to — 273° (Violle's formula),	8·19
Total to absolute zero,	83·40
One-third of this,	27·80
Observed by Pionchon,	27·18

Cadmium :

Naccari's formula gives the mean specific heat to absolute zero 0·05, from which the total heat would be,	29·70
One-half of this,	14·85
Obtained by Person,	13·66

Zinc :

Le Verrier gives as the heat to 0°,	46·9
Formula (Bède's) gives from 0° to 273°,	24·3
Total heat to absolute zero,	71·2
One-third of this is,	23·7
Obtained by Person (corrected),	22·6

Bismuth :

Taking Bède's formula, and correcting it so that it passes through Regnault's value, we get the equation

$$Q = 0·0308\, t + 0·00002\, t^2$$

which gives for — 273 to + 266·8,	16·57
One-half of this would be,	8·28
Obtained by Person (corrected),	8·88

Copper :

The formula worked out by the writer gives from — 273° to 1,054°,	143·
One-third of this is,	47·7
Observed,	43·3

Palladium :

Gives out to 0° (Violle),	109·8
From — 273° to 0° (Violle's formula),	15·1
Total to absolute zero,	124·9
One-third of this is,	41·6
Obtained by Violle,	36·3

(Violle remarks that this was an experiment of unusual difficulty, and that the result is approximate.)

Mercury:

	Calories.
Taking Regnault's value for the specific heat of solid mercury, we have for the total heat from absolute zero to — 40°,	7·46
One-third of this, ...	2·49
Obtained by Person, ...	2·84

Alloys:

The rule applies probably to alloys also, for instance, *d'Arcet's Fusible Alloy*. Its specific heat at 30° is 0·062 (Spring). The mean between 96° and — 273 is very probably smaller than this, but how much we cannot say, probably ten per cent. However, the above value would give for the heat from absolute zero, ...	22·88
One-third of this is, ...	7·63
Observed by Person, ...	5·96

With metals having a small latent heat of fusion, the inaccuracies of the formulæ for the specific heat may introduce relatively large errors. After all, there are too many deviations and variations to enable us to claim any strict rule regarding these coincidences. All that I wish to do is to call attention to the fact that for bismuth, cadmium and tin the latent heat of fusion is very nearly one-half the total heat in the solid metal at its melting point, while for silver, platinum, zinc, copper, palladium, mercury and d'Arcet's alloy it is close to one-third. The latent heat of fusion of silver may be assumed as probably the most accurate known, as also the curve of its specific heat, and in this very case the proximity of the ratio to one-third is the closest.

I might close by venturing a prediction. The best results we have for *gold* would indicate about forty-two calories as the amount of heat contained in the solid metal at the melting point. If the ratio in this case is one-third, as its similarity to silver, copper and platinum might indicate, its latent heat of fusion would be about fourteen calories. It has not yet been determined, to my knowledge.

APPENDIX.

ALUMINUM.

[See a *résumé* on this subject by J. W. Richards, in this *Journal*, February, 1892.]

First investigated by Regnault, in 1855, on very impure metal, obtaining 0·2056 between 25° and 97°, and allowing for the impurities present, he made the figure for pure aluminum 0·2181. Had he used the correct specific heat of silicon in making this allowance, he would have obtained 0·2200.

Investigated again by Regnault, a year after, on purer metal, obtaining a corrected value of 0·2143 (14°–97°).

Kopp used ordinary commercial aluminum, and obtained 0·2020 (20°–52°), as the mean of four determinations which varied from 0·1970 to 0·2070. This determination is, therefore, of very little value.

Mallet used chemically pure aluminum, and found by the Bunsen calorimeter 0·2253 (0°–100°).

Naccari (purity of metal not stated) investigated up to 300°, by the method of mixtures. His results lead to the formulæ:

$$S = 0{\cdot}2116 + 0{\cdot}000095\, t$$

$$Sm = 0{\cdot}2116 + 0{\cdot}0000475\, (t + t^1)$$

The mean 0°–100° would be 0·2164.

Richards used metal which analyzed 99·93 per cent. aluminum, the rest silicon. Temperatures pushed to 600°. Formulæ arrived at:

$$S = 0{\cdot}2220 + 0{\cdot}0001\, t$$

$$Q = 0{\cdot}2220\, t + 0{\cdot}00005\, t^2$$

Mean 0°–100°, 0·2270, being less than one per cent. from Mallet's value. The rate of increase with the temperature is similar to Naccari's observation. Total heat contained in the solid metal to its melting point (625°), by this formula, 158·3 calories.

LeVerrier finds the specific heat between 0° and 300° to be invariable, and = 0·22; between 300° and 530° also con-

stantly $= 0{\cdot}30$; between 530° and 560° an absorption of about 10 calories rendered latent; between 540° and 600° the specific heat again constant and equal to 0·46. For the total quantities of heat in the metal, he gives the following formulæ:

$$\begin{array}{llll} \text{Between} & 0^\circ \text{ and } 300^\circ & & Q = 0{\cdot}22\,t \\ & 300^\circ \quad \text{"} & 530^\circ & Q = 65 + 30{\cdot}0\,(t - 300) \\ & 540^\circ \quad \text{"} & 600^\circ & Q = 139 + 0{\cdot}46\,(t - 530) \end{array}$$

Q becomes about 170 calories towards 600°, and rises rapidly passing 200 before fusion at 620°.

Pionchon has recently published the following results:

$$\text{Between} \quad 0^\circ \text{ and } 580^\circ - Q = 0{\cdot}393\,t - \frac{291{\cdot}86\,t}{1517{\cdot}8 + t}$$

$$625^\circ \quad \text{"} \quad 800^\circ - Q = 0{\cdot}308\,t - 46{\cdot}9$$

Specific heat at $0^\circ = 0{\cdot}2010$; in the liquid state, above 625°, constant and equal to 0·308. He states that beginning at 580° the fusion starts, the metal losing its solidity, and between 623° and 628° the heat curve Q is nearly vertical. Pionchon's first formula gives for the total heat in the solid metal at the melting point 160·49 calories.

Latent Heat of Fusion.—In 1890, the writer determined the amount of heat in solid aluminum as near as possible to its melting point as 199·5 calories, and the heat in the molten metal as 229, from which he concluded that the latent heat of fusion was close to thirty calories. Since then, two sources of errors have been disclosed in this determination.

(1) The metal above 600° absorbs in advance some of its latent heat of fusion, the writer's observation in this regard agreeing with Le Verrier's, who states that the total heat exceeds 200 calories before real fusion occurs. If this phenomenon did not occur, the writer's formula would give the heat content at the melting point as 158·3, while Pionchon's formula gives 160·49, and it is these numbers which must be used in calculating the total heat absorbed during the change of state.

(2) The heat in the molten metal at its setting point is

very greatly modified by impurities present. The writer found the following heats in impure and pure metal:

Per Cent. Pure.	*Calories.*
96·9	229·0
99·9	254·0
99·93	258·3

The writer's results must then be considerably modified, in order to get the total latent heat. For the metal of greatest purity, the total calculated absorption between 600° and 625°, due to change of state, would be 258·3 — 158·3 = 100 calories. Pionchon's formula for the heat in liquid aluminum evaluated for the melting point gives 239·4 calories, and subtracting his lower value of 160·49, there is left 78·91 units as the latent heat. The writer's experiments would show that Pionchon's upper figure, 239·4, is probably nearly twenty units too low, since four experiments have given me 258·2, 258·9, 259·3 and 259·2, respectively.

ANTIMONY.

Professor Wilcke gave 0·063; Crawford, 0·0645; Kirwan, 0·086.

Dulong and Petit give 0·0507 (0°–100°) and 0·0549 (0°–300°), or in formulæ

$$S = 0{\cdot}0486 + {\cdot}000042\, t$$

$$Q = 0{\cdot}0486\, t + {\cdot}000021\, t^2$$

F. E. Neumann, using commercial metal, found its specific heat by the method of cooling as 0·0470.

Regnault:

0·05077. (61°–97°)

Bède gives the formulæ:

$$S = 0{\cdot}0466 + {\cdot}000040\, t$$

$$Q = 0{\cdot}0466\, t + {\cdot}000020\, t^2$$

Kopp gives:

0·0523 at 31° (unreliable)

Bunsen:

0·0495 at (0°–100°)

L. Pebal and H. Jahn found the following mean values:

$$Sm\ (-21^\circ \text{ to } -76^\circ) = 0{\cdot}0496$$

$$Sm\ (-21^\circ \text{ to } -0^\circ) = 0{\cdot}0486$$

$$Sm\ (0^\circ \text{ to } -33^\circ) = 0{\cdot}0495$$

Naccari derives the formulæ:

$$S = 0{\cdot}04864 + {\cdot}0000167\ t$$

$$Q = 0{\cdot}04864\ t + {\cdot}0000084\ t^2$$

BERYLLIUM.

Emerson Reynolds found 0·642 (20°–100°); while Nilson and Pettersson obtained 0·408 (0°–100°).

T. S. Humpidge investigated carefully through a range of temperatures and gives the formula:

$$S = 0{\cdot}3756 + 0{\cdot}00106\ t - 0{\cdot}00000114\ t^2$$

This formula evaluated for (0°–100°) would give 0·4248. It is therefore probable that Reynolds' value is much too high.

BARIUM.

The Russian chemist, Mendeléeff, gives 0·05.

BISMUTH.

Professor Wilcke made its specific heat 0·043.

Dulong and Petit found 0·0288, and Neumann 0·027 by the method of cooling.

Regnault made it 0·03084 (14°–99°).

Bède made experiments up to 200°, from which he calculated the formula

$$Sm = 0{\cdot}0269 + 0{\cdot}00002\ t$$

which would give for (14°–99°) 0·0292, about five per cent. lower than Regnault's result.

Kopp found 0·0305 (12°–60°), close to Regnault's figure.

Person found the specific heat of molten bismuth between 280° and 360° to be 0·0363.

Latent Heat of Fusion.—Dr. Irvine, Jr., determined that the

latent heat would raise the temperature of 550 parts of solid bismuth 1° F., equal to 305·5 parts 1° C. He then assumed Wilcke's figure for the specific heat of bismuth, which gives its latent heat as 11·92 calories. Had he used the specific heat found since by Regnault, his experiments would give 10·3. Or, had he used the specific heat at the melting point as determined by Bède's formula, he would have obtained 10·8 calories.

Person made experiments with molten bismuth, from which he calculated that at its melting point (266°·8) it contained 94·88 calories. But, assuming Regnault's value to be true to the melting point for solid bismuth, the heat in solid bismuth is 82·24 calories, from which the latent heat of fusion is 12·64 calories. If, however, we take Bède's determination of its increasing 0·00002 for every degree rise in temperature, the mean specific heat to the melting point would be 0·0322, the heat in solid bismuth at its melting point 86·00 calories, and the latent heat of fusion 8·88.

CADMIUM.

Regnault found 0·0567 (16°–98°) on metal containing one per cent. of impurities.

De la Rive and Marcet found 0·0576, at ordinary temperatures, by the method of cooling.

Kopp found 0·0542 (15°–60°) method of mixtures.

Bunsen found 0·0548 (0°–100°) by the ice calorimeter.

Naccari experimented up to 300°, and gives the following formula:

$$Sm = 0{\cdot}0546 + 0{\cdot}000012\ t$$

This evaluated for Regnault's range of temperature gives 0·0560.

Latent Heat of Fusion.—Person found 31·83 calories in molten cadmium at the melting point (320°·7), and subtracting the heat in solid cadmium at that point, using Regnault's value, the latent heat of fusion became 31·83 — 18·17 = 13·66. Had he used Naccari's formula for the heat in solid cadmium he would have obtained 18·7, and for the latent heat of fusion 13·13.

CALCIUM.

Bunsen found 0·1722 and 0·1686, mean 0·1703 (0°–100°), by the ice calorimeter.

CERIUM.

Dr. W. F. Hillebrand gives 0·0448, at ordinary temperatures, determined on metal 95 per cent. pure. allowing for the impurities which were mostly iron and didymium.

CHROMIUM.

Kopp found 0·1000 (15°–60°); but since he found that of iron, with a larger atomic weight, to be greater than this, he concluded that this number must be too small, and supposed it due to the impurity of the material he was working with.

COBALT.

Dulong and Petit found 0·1498, by the method of cooling.

Regnault gives 0·10696 (13°–99°).

De la Rive and Marcet obtained 0·1172 as the mean of three experiments by the method of cooling. Regnault observes, however, that specimens containing carbon gave him as high as 0·117, but he took the smallest value as belonging to the purest metal.

Pionchon investigated up to 1,160°. He found the specific heat at 0° to be 0·10584, his formula up to 900° being

$$Sm = 0{\cdot}10584 + 0{\cdot}00002287\, t + 0{\cdot}0000000219427\, t^2$$

This formula evaluated for Regnault's range gives *Sm* (13°–99°) = 0·1086, about 1·5 per cent. higher than Regnault's value. At about 900°, however, Pionchon observed a sudden change in the specific heat, so that above 900° the mean specific heat to 0° is expressed by the formula:

$$Sm = 0{\cdot}124 + 0{\cdot}00004\, t - \frac{14{\cdot}8}{t}$$

He could not definitely determine just how much heat was rendered latent in this change at 900°.

COPPER.

Wilcke found 0·114; Dr. Crawford, 0·1111; and Dalton gave 0·11, the latter by the method of cooling.

Dulong and Petit found 0·0949 (0°–100°) and 0·1013 (0°–300°), from which follows the formula:

$$Sm = 0{\cdot}0917 + 0{\cdot}000032\ t$$

Regnault gives 0·09515 (17°–98°); Dulong and Petit's formula evaluated for this range gives 0·09535.

Bède obtained a considerably lower result, giving up to 250°.

$$Sm = 0{\cdot}0910 + 0{\cdot}000023\ t$$

which gives values at (15°–100°) about two per cent. lower than Regnault.

Kopp obtained values between 0·0895 and 0·0949, average 0·0925 (15°–60°).

Naccari worked up to 325°, and gives the formula:

$$Sm = 0{\cdot}0921 + 0{\cdot}0000106\ t$$

which gives at 17°–98°, 0·0933. This result is almost the same as Bède's, but for higher temperatures would be much below his.

Le Verrier says that the specific heat of copper does not increase regularly with the temperature, but is constant between certain limits, that is:

Between	0° and 360°,	0·104
	360° " 580°,	0·125
	580° " 780°,	0·090
	780° " 1,000°,	0·118

Further, that at the points where the changes occur there is heat rendered latent, about two calories towards 350°, two calories towards 580°, 3·5 calories towards 780°. He states that the total heat in the copper is 117 calories towards 1,020°.

In connection with Prof. B. W. Frazier, the writer has made a particular study of copper, reaching the conclusion that none of the above critical points occur, and that the specific heat increases regularly with the temperature according to the equations

$$S = 0{\cdot}0939 + 0{\cdot}00003556\,t$$

$$Sm = 0{\cdot}0939 + 0{\cdot}00001778\,t$$

$$Q = 0{\cdot}0939\,t + 0{\cdot}00001778\,t^2$$

These formulæ were the true expressions of the results obtained up to 900°, and at none of the temperatures designated as critical points by Le Verrier were any deviations noticed. It would have been impossible for an absorption of 0·5 calorie to have occurred without having been detected. The ratio of the specific heat of copper to that of platinum throughout this range did not vary one-half of one per cent. from 2·96, showing that the *ratio* of increase of specific heat with the temperature is the same in both metals.

Latent Heat of Fusion.—The mean value of six experiments on the amount of heat in molten copper at the melting point have given us 162·0 calories. The above formula evaluated for 1,054° gives for the solid copper 118·7 calories. We have therefore determined the latent heat of fusion as 43·3 calories.

DIDYMIUM.

Hillebrand obtained 0·04563 (0°–100°) in the ice calorimeter, allowing for 0·4 per cent. of silicon, 0·3 per cent. of iron and 0·1 per cent. of aluminum which were in the specimen.

GALLIUM.

Bettendorf obtained 0·079 (12°–23°), for solid gallium. Tomassi (*D'Electrochimie*, p. 226), gives the specific heat of liquid gallium as 0·0802, and the latent heat of fusion as nineteen calories. I do not know the name of the investigator who determined these.

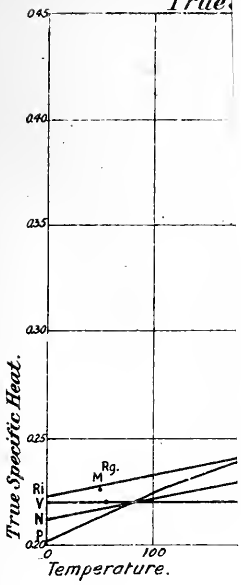
GERMANIUM.

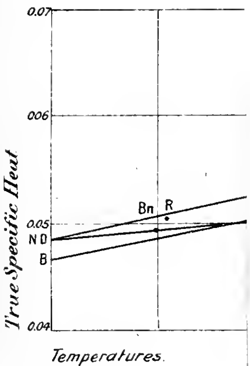
Nilson and Pettersson found the following mean specific heats:

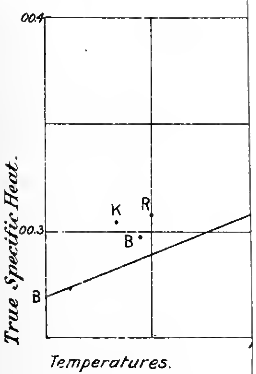
0° to 100°,	0·0737
0° to 211°,	0·0773
0° to 302°,	0·0768
0° to 440°,	0·0757

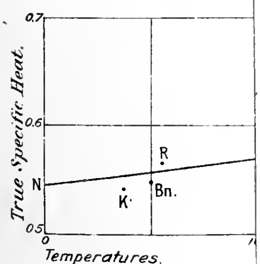
As there is evidently first an increase and then a decrease, no simple formula can be derived to express these results.

True









ɟave it
by the

ɿ9 fine.
°–100°
up to
.elting
0·0345
igures
.nt, or
ɿf any

ʼ4 and

at the

reater

inum,

ırther
2, 85·3
mula,

ↄ·143;

.ining

ɿ98
50
:18
:55

which would lead to the formulæ

$$Sm = 0{\cdot}1062 + 0{\cdot}000028\,t + 0{\cdot}00000008\,t^2$$

$$S = 0{\cdot}1062 + 0{\cdot}000056\,t + 0{\cdot}00000024\,t^2$$

It may be here remarked that all later investigators have reached similar formulæ of three terms, which means that the specific heat of iron increases more rapidly than the first power of the temperature. It should be borne in mind that these formulæ were verified only to 350°.

Regnault found 0·11352 (19°–98°), and after the same piece had been heated to redness 0·11380.

Bède obtained the following results:

15° to 100°,	0·11230
16° to 142°,	0·11533
20° to 247°,	0·12331

From these observations, he deduces the formula

$$Sm = 0{\cdot}1053 + 0{\cdot}000071\,t$$

but it can be seen from the data obtained that the value for 247° was higher than it should have been if the rate of increase had remained constant. A formula of three terms should, therefore, have been derived to fit the data, and he should have given

$$Sm = 0{\cdot}1050 + 0{\cdot}000065\,t + 0{\cdot}000000018\,t^2$$

It will be observed that the coëfficient of t^2 is smaller than in Dulong and Petit's formula, showing the curve to be nearer to a straight line.

Byström gives the true specific heat of iron, as deduced from his experiments, at every 50° up to 300°, as follows:

		Differences.
0°,	$S=$0·111641	
		0·000728
50°,	0·112369	
		0·001426
100°,	0·113795	
		0·002154
150°,	0·115949	
		0·002872
200°,	0·118821	
		0·003590
250°,	0·122411	
		0·004308
300°,	0·126719	

These data would lead to the formulæ

$$S = 0{\cdot}11164 + 0{\cdot}00000718\, t + 0{\cdot}0000001436\, t^2$$

$$Sm = 0{\cdot}11164 + 0{\cdot}00000359\, t + 0{\cdot}0000000479\, t^2$$

This formula differs from the previous ones in having a much larger value of the constant, a much smaller coëfficient of t and a larger coëfficient of t^2, which is shown on the diagram by the curve starting higher, being quite flat for a distance and then rising rapidly. This formula evaluated for Regnault's range gives Sm (19°–98°) 0·1127, about 0·75 per cent. below Regnault's value.

[*To be continued.*]

NOTES ON ANCIENT TEMPLE ARCHITECTURE.

BY JOHN M. HARTMAN.

[*Abstract of remarks made at the stated meeting, held April 19, 1893.*]

The Pyramids.—Herodotus tells us the stones were elevated with a machine made of short pieces of timber. This description answers to the tilting process, and that they blocked up after each tilt: a slow but sure method. By the same process the blocks could be taken sideways to their destination. The inclined gallery leading up to the King's Chamber has a ledge of stone projecting out about 24 x 40 inches high on each side. In the top of this projection are holes at regular intervals, evidently chock holes to block up after the granite blocks of the chamber and for taking up the sarcophagus. The Sphinx is carved from rock left in position when excavating for a place to set the pyramids. The stratification of the rock shows across the body and face.

Luxor.—At the temple of Luxor they have recently uncovered, at the bottom of the grand colonnade, a carving, showing a horseman following a chariot, which is the only instance of the picturing of a horseman in all Egyptian hieroglyphic writing. The two obelisks of this place (one of which is now in Paris) are the finest in the world, and

the carving, after 3,300 years, is as sharp and well defined as when made. They are of gray granite, highly polished.

The temple of Medinet Habu has sandstone girders, 24 x 30 inches and 15 feet long from column to column. The underside of these girders has fallen out in the form of an ellipse, showing the effort of nature in long ages to rid herself of surplus material. The remaining part has not broken in two, but forms an elliptic arch.

The Tombs of the Kings are long tunnels, driven in on a stratum of argillaceous schist. As the strata are somewhat distorted, the floor of the tunnel was driven to keep in this schist, as the adjoining rock could not be used; hence, the irregularities of the floor. This argillaceous schist, being very porous, has absorbed a large quantity of the paint employed in the pictures with which the walls are decorated, a fact which accounts for the almost perfect retention of the color after 3,300 years.

The pink granite (syenite) statue of Rameses the Great, sitting on his royal chair, was destroyed with fire and water by Cambyses, who could not break it in any other way. The broken statue now lies on its face. It is 21 feet across shoulders and originally was 60 feet high and weighed 850 tons. It is a perfect piece of Egyptian sculpture and brightly polished. This was the masterpiece of the old world, and nothing like it has been attempted since.

Edfou.—Some of the sandstone columns of this temple are enamelled in white. This enamel is so firmly laid on that it cannot be separated by breaking.

Philæ.—Into the walls of the temple of Philæ is built a large boulder, which has been surfaced off and on this the deed of presentation of the island to the priests of Isis, by Ptolemy II, was inscribed. The temple is in ruins, but the deed is perfectly preserved.

Syenite Quarries at Assouan.—The only place in the East where syenite, or pink granite, is found in quantity is at Assouan, and from this quarry came the columns of the Greek and Roman temples at Constantinople, Rome and Baalbec. To get the proper idea of the size of this quarry, which has been drawn upon for material by all ages,

it is best to ascend to its highest point, and to bear in mind that the sands of the desert have covered its greater portion in later years. Near the top of the quarry is an opening containing a monolith 12 feet square and 100 feet long, detached and raised up, but not removed. In the long after years from the time it was detached, the attempt has been made to break the monolith in two by cutting a groove around it, but the brains and hands of the masters who detached and raised it were not there and the trial of simply breaking it was a failure. The quarrying of one of these monoliths was a work of time. The top of the quarry having been dressed off, the outline of the monolith was laid off. Around this outline a channel about two feet wide was chiselled and broken out to the depth of the monolith. This channel was cut with a gouge or half-round chisel, about half an inch wide. A groove six inches deep was cut on each side of the channel and the granite broken out between the two grooves. The chisel marks left on the side face of the quarry vary, but are about six inches high or deep. Some of the cuts are perfectly uniform, showing the good workman; while others are irregular, showing the apprentice's hand.

After the first cut was started a second workman started in behind the first and took another six-inch cut; this process was followed by others until the bottom of the monolith was reached. All around the bottom of the block, square taper openings, 3 inches apart, about 3½ inches high by 5 inches wide, were cut wedge-shaped about 6 inches inward, after which each hole was wedged and the monolith split off. These taper holes with their sharp square corners are a marvel. Any mechanic trying to cut a square hole through a piece of cold iron with a hammer and chisel will appreciate what it means to make these openings after he has broken some of his chisels. From the fact that the monoliths left in the quarries lie at an angle, it would appear as if they had resorted to tilting and blocking to elevate them. In the limestone quarries they took a cut about twelve inches deep, and much coarser, as the material, being softer, permitted the use of a longer chisel, or gouge;

but with this hard, tough syenite, they had to use shorter chisels and take finer cuts. There is nothing in Egypt to prove the use of copper tools in stone-work, but they undoubtedly had good steel tools. The conquerors who succeeded the Egyptians, having nothing but fanaticism and insolence for their portion, could not make a pound of iron or steel, and from that day to this have been destroying the works of the old masters, to rob them of the iron used in their construction. The result is that even the tools of the ancient workmen have disappeared.

In Egypt all work is done sitting down. They turn table legs and all other wood-work on a lathe on the ground. The work is revolved back and forth by a large bow, worked with the right hand, the gouge or chisel cutting only when the work revolves forward. The left hand guides the outer end of the gouge or chisel, while the inner end is held to the steady rest between the first and second toe of the right foot. The first and second toe of an old turner lengthens out beyond the other toes, and the space between them increases. They grow like the thumb and first finger, as they gradually assume their new functions.

Jerusalem.—Jerusalem was originally a Phœnician town and summer resort from the heat of the lowlands. Good masonry with large blocks is found in the town wall which the founders built. When Solomon built his temple, he hired skilled workmen of Hiram, King of Tyre, a Phœnician city, to erect the masonry. Part of the temple was built on rocks levelled off, and where the hill sloped off, piers were carried up and arches sprung across them to get sufficient area for the temple. These piers contain blocks 30 inches square, 32 feet long, and are as good to-day as when built. Solomon used much wood in the temple, and when it was destroyed by fire, the arches, being of limestone, were calcined and ruined. When the Jews built the second temple they rebuilt the arches on the old piers. The second temple was smaller than the first, and when that was burned the arches were again destroyed, though only partly. Subsequently the Romans rebuilt the arches and temple, which accounts for the three different styles of masonry, concern-

ing which there has been so much speculation. Just by the Jews' wailing place, on the outside of the temple, are the large skewbacks of an arch connecting the temple with Mount Moriah, Solomon's home. From the size of these skewbacks, the arch must have been a masterpiece of Phœnician work. Josephus speaks of this arch.

Damascus.—The Phœnicians founded Damascus, and the Phœnician gate, with its massive stones and grooves in which the door slid up and down, still exists. In what is said to be a triumphal arch, built like the façade of a Greek temple, occurs an arch sprung across on the two middle columns. The Greek square is carried over the arch. The arch is ancient, and no date can be assigned to it.

Baalbec.—In the foundation of the first temple of the Sun are found the three large stones about which the world is still puzzled to know how they were transported and elevated to their position. They weigh 1,000 tons each. One left in the quarry weighs 1,350 tons. The piers and arches supporting the temples are the counterpart of those under Solomon's temple at Jerusalem, and no doubt were erected by the same hands. They are as good to-day as when built, probably 3,500 years ago.

The second temple of the Sun, of which there are only six columns and frieze remaining, has no cella, and antedates the Roman temples which always have the cella. Its age is unknown and the style of architecture is in advance of the Greek corinthian, which has been copied from it and the fluting added to the columns. The workmanship of these ancient columns is unsurpassed. They are 7 feet 3 inches in diameter and 75 feet high.

The temple of Jupiter, built by Antoninus Pius, is the masterpiece of temples in design, material and workmanship. The columns, 6 feet 4 inches in diameter, were faced off absolutely true, and polished, so that when the two ends met they bore evenly over the whole surface. The polish on these columns is perfect after 1,800 years. Some of the columns overthrown in the earthquake 135 years ago show their construction. In the centre of each end of the sections of the column, was placed a large wrought-iron

dowel run up with lead. So well has this been done that one of the columns having been thrown over against the cella, is still leaning against it and does not come apart.

The quarries of Baalbec are the oldest in the world, and the manner of quarrying stone is the same as that of Assouan already described. It is the Phœnician method and was doubtless introduced into Egypt by this people, who were hired out to construct the great works of the old world. The Phœnicians were the master-builders of the world and taught the other nations their art. When the history of the nations comes to be written, the Phœnicians will be found in the advance for their influence on the arts of civilization.

CAUSES OF FIRES.

BY C. JOHN HEXAMER.

[*Continued from p. 70.*]

I wish to call particular attention to the fact that the explosiveness of light petroleum products cannot be effectively lessened or neutralized by adding various substances to them. Numerous claims have been made for substances intended to be added to gasoline, and the naphthas, to reduce their explosibility. So far as I know there exists no substance which even to a slight degree lessens the inflammability of petroleum and its products. A stop should be put to the sale of such humbugs. The writer, in his experience as expert, has frequently found that people have become negligent and exceedingly careless in handling the light petroleum products, believing them to have been made safe by such additions. As a good thermometer is not accessible in every household, the simple test of pouring a few drops of the oil in a saucer and applying a match near the surface will suffice. If the material readily flashes and burns, reject it as unsafe.

In order to decrease the danger from lamps, so-called safety lamps have been invented. These are made of

glass, enclosed in metal cases, which protect the glass receptacles. Westland's lamp has, experimentally, proved successful, although the writer has no further evidence of how it has worked in practice. This lamp consists of a globe of glass, containing the oil, surrounded by a concentric sphere, containing water charged with carbonic acid gas under pressure. As soon, therefore, as the lamp is broken, carbonic acid gas is set free, tending to extinguish the flames.

Hanging lamps should be suspended from metal chains, and not from cords, for should the fibres burn through the lamp falls. Kerosene lamps should be filled in daytime only. Never attempt to fill a lamp while it is burning, or near an artificial light or fire. No flame, be it gas or oil, should be nearer than eighteen inches from bare woodwork at the sides and thirty-six inches from the ceiling.

Gasoline stoves are exceedingly dangerous and should not be used. In country residences, gasoline vapor, or, as it is frequently called, gasoline gas, is sometimes used. Where gasoline machines are used, the apparatus, especially the carburetting arrangement, should be placed at least fifty feet from all other buildings. The gas machine building should be on a piece of ground lower than the other buildings, so that the gasoline vapor which may escape, and which is heavier than air, may flow away from the buildings. Carefully see to it that all supply pipes descend towards the machine building, so that any vapor which may have condensed in its passage from the carburetter to the dwelling may flow back into the carburetter. Care must be taken to have a drip-cock attached to every jet, so that the pipes may be well emptied of gasoline before lighting the vapor. Gasoline vapor is extremely explosive and dangerous.

The electric light is daily coming more into use, and when properly installed is the safest. Great care should be taken to have all wires properly insulated, all connections in wires well made, the proper amount of cut-outs, switches and safety catches, and, for arc lights, provision should be made by wire guards to prevent the falling of the glowing

carbon points. One of the greatest hazards is caused by improper insulation, as moisture will cause an electric current to pass from one wire to another, especially through water which contains salts, such as lime, which it dissolves in passing through ceilings or walls.

Many fires are caused by matches, especially the so-called parlor or phosphorus match. These should always be kept in metal or earthen safes. Heavy earthen jars, with covers, are very good receptacles for them. All match safes should have covers. The most dangerous way of keeping them, is that often employed in dwellings, *i. e.*, in paper boxes, or loosely in kitchen-dresser drawers, in which they are often ignited by the motion of opening or shutting the drawer. Fires have been caused by matches through rats and mice. These vermin, by gnawing them, set them on fire, sometimes in the boxes, or at other times, after carrying them great distances through floors and hollow partitions to their nests, usually located near warm pipes.

So-called safety matches should, as far as possible, be employed. The safety match, which if I remember rightly, was first invented by Böttger, at Frankfort, in 1848, is now made of two kinds: those which are free from phosphorus, the amorphous variety of phosphorus being contained in the sand-paper; and secondly, those varieties which are free from phosphorus, both in the match and in the sand-paper. To the first kind belong matches made of a pasty mass, the main constituent of which is sulphuret of antimony and potassium chlorate. Secondly, the amorphous phosphorus, mixed with some very fine sand (or other substance which will be apt to promote friction), and with glue, and spread on the box in which the matches are contained. The friction surface on the box consists of nine parts of amorphous phorphorus, three parts of glass, seven parts of pulverized pyrites and one of glue. As is well-known, these matches can readily be ignited on surfaces containing this composition, but not when rubbed on other rough surfaces. These matches are now sold to a large extent in our country and are known as Swedish matches, as they are manufactured at Jönköping and are marked

"Säkerhets-tändstickor," meaning security fire matches. The matches belonging to the second category, *i. e.*, those which neither contain phosphorus nor require a phosphorus-coated surface, according to the analysis of Wiederhold, contain eight parts of chlorate of potassium, eight parts of sulphuret of antimony, eight parts of red oxide of lead and one part of gum senegal. Weiderhold suggested the following composition: chlorate of potassium, 7·8 parts; hyposulphite of lead, 2·6 parts; gum arabic, 1 part.

Matches are not a safe means for "lighting up," as it is more difficult to extinguish matches, especially the ordinary phosphorus match, than is generally believed, and if especial care be not taken to extinguish them, they glow for some time and frequently cause fires when carelessly thrown away.

In order to safely light gas, where permanent electric attachments have not been introduced, several devices have been constructed, among which are the electric torch. Other stationary devices, such as electric gas lighters attached to brackets or chandeliers, can be highly recommended for their great safety, and are now so cheap that there is no excuse for not installing them.

Smoking has frequently caused fires, especially in libraries and offices. The writer, several years ago, was called to investigate a case in which a gentleman thought that an amount of waste paper in his paper basket had been ignited by the concentrated rays of the sun through a defective window pane, which, as he believed, had acted as a lens, and thus ignited the paper; but upon further investigation a cigar stump was found in the bottom of the basket, among the burnt paper, and probably had been the originator of the fire. Great care should be exercised to place lighted cigars in metal or earthen receptacles. They should never be thrown away carelessly.

Wooden spittoons filled with saw-dust have caused fires, and cases have been observed where ignited spittoons burnt through floors and dropped into the cellar below. Such receptacles should be of metal or terra-cotta, and where an absorbent filling is desired, sand or gravel should be used.

It is a very bad and dangerous habit to smoke in bed, especially when indulged in as an antidote for alcoholic excesses. Fires and loss of life have been the consequence. Another cause of fires is reading in bed with lights near the bed-clothing.

Do not light pipes, cigars, gas, etc., with pieces of paper, and then carelessly throw these away without noticing whether they are extinguished. Persons frequently leave the room immediately thereafter, and the paper re-kindles. The draught produced by the opening and closing of the door may be sufficient to re-kindle smouldering paper.

One of the first requirements, not only of civilized life, but also to secure immunity from fire, is cleanliness. The fire hazard of any place increases with its untidiness. Not only should those places which are exposed to the view of strangers be kept clean, but especially those dark corners which would but seldom be noticed, such as lofts, out-of-the-way closets under stairways and cellars. It may relieve the dryness of this technical subject to note, *en parenthese*, that our ideals of cleanliness have been materially ameliorated, and are still improving. To quote Stevens, on the conditions of life in the time of Elizabeth and Shakespeare: "The sluttery of ancient houses rendered censers, or fire-pans, in which coarse perfumes were burnt most necessary utensils. Lodge tells us that Lord Paget's house was so small that 'after one month it would wax unsavory for hym to contynue in it.' In a letter of the Earl of Shrewsbury, respecting his prisoner, Mary, Queen of Scots, we read, 'That her majesty was to be removed for fyve or sixe days, to klense her chamber, being kept very unklenly:' and in the Memoirs of Anne, Countess of Dorset, we are informed of a party of lords and ladies, who 'were all lowsy by sitting in Sir Thomas Erskin's chamber.'"

Care must be taken to properly store waste paper clippings, straw, rubbish, or packing material, which may have been left in the house. Frequently this is put in places where it is exposed to heat, and liable to cause a fire.

When repairs are made, particular care should be taken to watch the workmen closely, so as to prevent them from

carelessly setting away tinsmiths' fire pots, plumbers' gasoline furnaces, and the like.

Spontaneous combustion is a frequent source of fire in dwellings. We shall treat this topic at length later, and therefore will not digress here, but give the caution to be careful of oily waste and rags, especially of the linseed oil rags left by painters, "finishers," etc.

It is a very hazardous practise to place clothing hung on clothes-horses, near stoves to dry (often done in wet weather) and leaving it there overnight. It seems like self-stultification to say that under no circumstances should clothing which has been cleansed by the lighter petroleum products, alcohol, chloroform, or ether, be placed near a fire, did we not know by sorry experiences that this is done. After cleaning clothing with such substances, which should never be done at night or near an artificial light or fire, they should be hung outside and thoroughly aired until there is no doubt that the volatile substance has vaporized. Not only numerous fires, but also serious explosions and loss of life, have been caused by carelessness in handling these products. The terrible accident that happened several years ago will be remembered, where several persons were killed by sprinkling benzine on a parlor carpet to preserve it against moths. The vapors escaped from the room, and travelled for some distance to the kitchen fire, causing a tremendous explosion, through which several unfortunates lost their lives. It must be well remembered that petroleum vapors are heavier than the air, and therefore do not readily escape through open windows. They sink to the floor, and if a light be placed near them, an explosion occurs.

Explosions have occasionally occurred of kitchen-range boilers, used for heating water, causing the fire in the range to be thrown out. Especial care should be taken to frequently change the water in the boiler on ironing days, when, through the great heat used to warm sad-irons, the waterback in the range is intensely heated, causing the water to be vaporized, and creating a considerable steam pressure in the boiler. To overcome this, one of the hot water spigots should be kept running continuously on such days,

so that steam which may have accumulated can escape. In winter time there is danger of explosion from the freezing of water supply pipes. Before firing up in cold weather, examine whether the water in the pipes is frozen; if this is the case, draw your fire and send for a plumber to thaw and repair the pipes before attempting to build a fire.

This series of articles has to do with fire hazards only, and we will not, therefore, treat of dwelling house construction here, which can better be done in a special essay; but we must touch on a topic demanding frequent and reiterated allusions by our daily and periodical press; that is, how to act in case of fire. For then even the coolest, metaphorically speaking, lose their heads, many become crazed with fright, and even strong men stand powerless as if stunned. He who remains most collected will be the one to render the most efficient service. Excited haste is almost as bad as no help; but the cool, rapid worker is the man needed in the work of saving. It is, for this reason, of importance that every person should exactly and frequently think about, and lay out his plans how he would work and act in case of fire. In going into a new house or hotel, he should find out where the fire escapes are located; how they are arranged; if they could be of value in case of fire, and not trust himself to the elevator for reaching and descending from his room, and then be entirely helpless in case of fire. The only way in which a person can be cool under trying circumstances, is by knowing exactly what to do at the time, as only the man who knows is self-reliant. In going into a theatre the same precaution should be taken. The writer has, in other papers read before the Institute, pointed out the fire hazards encountered in playhouses, and never settles in his chair when he visits a performance until he has satisfied himself of the most available exit from his location. All who value their own lives and the lives of those dependent on them, should do likewise.

A person should not only know the means of access to fire-escapes, stairways, and so on, but also how he may reach the roof of his dwelling place if his escape is cut off.

There is, I believe, a law in this city requiring trap-doors

on roofs; but numerous houses are without this essential. When a trap-door leads to the roof, a ladder (and a convenient one) should be permanently attached thereto. If this is not the case, the way to the roof is apt to be cut off at the very moment when it is most needed. A simple and reliable fire-escape should also be provided.

When a fire breaks out at night, do not stop to dress, but slip on shoes, wrap yourself in a blanket, not a cotton-filled quilt, and take the nearest and most accessible way to escape, bearing in mind that the shortest distance between two points is a straight line. In all cases be careful to close the doors after you. It is of the utmost importance to shut all doors and windows which might add to the draught. If the room be already filled with smoke, it is best for persons to crawl on their hands and knees on the floor, as the heated gases and smoke ascend and are more dense as they accumulate near the ceiling than they are at the floor. If the smoke is very suffocating, a piece of flannel (and if possible, a wet one), or any rag, woollen shirt or dress, held over the mouth and nose will greatly protect the lungs from injury. Avoid, as much as possible, inhaling the hot air and smoke.

If the means of escape through the doors on the first floor or the trap-doors on the roof, are cut off, and no fire-escape is at hand, hurry to the room least affected by smoke and hot air, and make a rope of shreds of bedding, attaching one end of the rope, and by this means try to descend to the ground. *Never jump from windows unless you are satisfied that all other means of escape are impossible.* If this is your only alternative, get persons on the outside to hold a carpet or a blanket, or even a large overcoat, and jump on it, or throw out bedding, mattresses, etc., and leap on these.

If a person's clothing has caught fire, wrap a blanket (not a cotton-filled quilt) around him quickly as this will exclude the air, and therefore the oxygen, and cause the fire to be extinguished. Woollen goods are to be preferred under such circumstances as they are less combustible, ammonium carbonate being given off during their ignition, which tends to retard and even extinguish flames; but in a case of this kind, one should never run out in the open air for aid as the

amount of oxygen fed to the flames will only be greater and cause the ignited garment to burn more furiously.

To extinguish fires, do not wait for the fire department to come. When a fire originates, immediately give the alarm before attempting to extinguish it yourself; then do not disdain to use even the simplest fire appliances at hand. A bucket of water thrown on during the first moments of ignition is worth more than all the fire engines in the city half an hour afterwards. Proceed on your hands and knees to where you think the fire originates, thus avoiding the smoke, and get as near as possible to the point of active combustion. Apply the water directly at the point of ignition and as near as possible to the bottom of the burning substance, as the water, which immediately vaporizes into steam, rises through the mass and tends to extinguish it much more effectually than by pouring the water on top of it.

Chimney fires can be readily extinguished by throwing salt down the chimney, as gas is evolved which extinguishes them.

Burning fats, rosins, pitch, etc., can be successfully extinguished by placing wire gauze of very fine mesh over the burning mass. The reason for this is (as is the reason for the efficiency of the Davy safety-lamp) that flames are not transmitted through wire gauze, as the wire being a good conductor, conducts away the heat, preventing the flames from passing. This remedy, however, is not usually available. Sand is a very good means for extinguishing fires originating in pitch, tar, petroleum and its products. Water is of little value; sand, on the other hand, when thrown on burning substances, cuts off the supply of oxygen from the air, causing the flames to be extinguished. If nothing better is at hand use a bucketful of ashes.

Do not, in case of fire, attempt to remove unnecessary or cumbersome articles. The writer has seen occurrences which were as absurd as that, frequently related, of the woman who attempted to save the mirror by throwing it out of a window from the top story and carried the bedding down-stairs.

We have in the United States devoted almost our whole attention, not so much to saving life in case of fire, as to extinguishing the fire, and for this reason, although we surpass the world in our appliances for extinguishment, we are far behind several European cities, such as the fire departments of Paris, Berlin, etc., in means for saving life.

Of all methods for saving life, the so-called "Rettungs-Schlauch," which means a life-saving hose, or, as it might be better translated, saving chute, has proved the best. It can in almost every case be used with safety for saving a number of persons. This device consists of a chute of heavy, strong sail cloth, and has been used to a height of eighty feet without danger of tearing. According to Magirus, a German authority on these matters, every metre of the chute should weigh at least 850 grammes, and it can be used, even at considerable heights, in an almost vertical position, but must then be turned spirally so as to allow the person in it to be shot through it slowly.

Unfortunately, at the time of the Ring Theatre fire, Vienna, they had but two of these devices, or many more persons would have been saved, as the apparatus did excellent service.

Timid or hysterical persons, objecting to enter the chute, should be forced into it. Of course, but one person at a time should be allowed to enter the chute. When cool, collected persons have charge of it a great number of lives can be saved in a short time. The number of persons which have thus been saved since its introduction about sixty years ago is astounding. Modifications of this old device have, I am told, been patented in this country, but these could be generally introduced without infringing any so-called "claims."

The invention of Hausmann and Richenberger is more recent; it consists of a cloth from 20 to 30 metres long and a width of from 300 to 320 centimetres, made of very heavy sail cloth. The person to be saved slides from a window into the middle of the inclined concave surface, and thereby, it is claimed, "slowly" slides down the middle of it.

The jumping cloth is an invention which has been used in Europe for a long time, and if it had not been for such aids many more would have been killed at the great theatre fire at Vienna. These cloths are generally three to four metres square, woven without a seam. In order to strengthen them from four to five belts or strips are tightly sewed onto the lower surface crosswise so that the cloth is subdivided into twenty-five equally large squares. It is then strongly hemmed in on all sides and a strong tarred rope with handles is tightly sewn on the edges. According to quality, a cloth of this kind costs from twenty to thirty-five marks. The cloths are held by persons on the street and those in danger jump into them. Of course, the second person is not allowed to jump until the first is removed from the cloth. There is but a slight danger connected with leaping into these, and thousands of persons have been saved by this contrivance. Had our police and fire department been supplied with such contrivances, we would have been spared the heartrending scenes at a Spruce Street dwelling house fire several years ago.

Several European fire departments have regularly drilled corps using small "hook ladders" which have been of excellent service. These ladders are light and strong, about twelve feet in length, with hooks at their ends. By attaching these to the windows a well-drilled corps can scale the highest building in an incredibly short time, carrying "saving chutes," etc., with them.

Numerous other inventions have been devised for saving life, but they are, as a rule, so complicated that it is utterly impracticable to use them. Inventors, as a rule, forget that an apparatus, which it is difficult to use, even at ordinary times, cannot be employed when people are frightened, and many fire-escapes can be seen on our streets at present which only a skilled acrobat could descend at his leisure in daylight, and are of no practical value. Many fire-escapes, although convenient, would soon become useless in case of fire. Thus we see some of them consisting of stairways enclosed with sheet iron, as for example the fire-escape on one of our largest hotels. The large sheet-iron boxes, in

case of fire, would act as excellent smoke flues, and people attempting to descend them would, in all probability, be suffocated. In order to keep people from falling, instead of sheet iron, a strong wire netting should be placed on the outside, which would not transform the escape into a smoke flue. The main ladder of a fire escape should never cross a window or other opening in a wall, as it would be impossible for persons to pass windows with the flames striking out of them. A light iron porch should be erected on every floor which should connect the windows with the main ladder. The best form of fire-escape is the brick tower, not permissible for dwellings, but its introduction should be made obligatory for hotels, tenements, etc. (An illustration is to be found in my paper, "The Construction and Interior Arrangement of Buildings Designed to be used as Theatres," this *Journal*, July, 1892.)

The appliances devised for saving one's self are, as a rule, of very little account. Several small devices have been invented, which, being simple, can be used by men, although it is not probable that women or children could use them.

Appliances which make it possible for firemen to breathe in compartments filled with smoke would be useful additions to our fire service, and would increase the efficiency of our firemen as life-savers. They have been used with success in Europe.

The first apparatus of this kind was devised by Colonel Paulin, Chief of the Paris Fire Department, between 1830 and 1845. It consists of a strong leather mask and blouse and a closed cape, into the inner part of which the smoke and hot gases from the fire cannot enter. Eyeholes, covered with strong glass plates, are inserted in the mask. In a position near the mouth a strong signal pipe is attached, while on the breast a leather hose two centimetres in diameter is connected with an air pump, which supplies the fireman using the device with air, and also the necessary oxygen for a lamp which is attached to the forepart of the suit.

Metz, the founder of the modern German Fire Department,

who first employed this apparatus in Germany, gave it a different form, by making it stronger and putting a cage in front of the glass eyepieces, so that these could not readily be broken. He attached the air tube in the back instead of the breast, which was more practicable, and replaced the blouse by an armor which went to the waist. Similar appliances with different improvements have also been made by Magirus, Kühfuss, Schultz, Hönig and Feltz.

It is important that fire departments, as well as the different police stations, should be well supplied with stretchers and implements for carrying away and properly attending to the wounded. Since the introduction of our police patrol service there has been a decided improvement in this respect. Would it not be possible to utilize these forces as life savers, equipped with the necessary appliances, at fires?

When a person has been partially suffocated with smoke or carbonic acid gas, place him on his back, with his head raised. Rinse the mouth and throat with water; sprinkle the head and face vigorously with cold water, and pour cold water over the body, open all tight garments, and continue the use of cold water until the arrival of a physician. When parts of the body are burnt, cover these with wadding or cloth saturated with linseed oil or lime water.

Every police patrol wagon and fire department station should be provided with a medicine chest, which should contain brandy, vinegar, alcohol, spirits of mustard, sal ammoniac, linseed oil, soda, burnt magnesium, sulphate of iron, peppermint tea, as well as a tourniquet and syringe, bandages, linen, brushes, sponges, shellac, etc., while a good supply of blankets, mattresses and stretchers, besides the above-mentioned saving devices, should not be wanting.

[*To be continued.*]

THE ACTION OF AMMONIA GAS UPON MOLYBDENYL CHLORIDE.

BY EDGAR F. SMITH AND VICTOR LENHER.

[*Read before the Chemical Section, May 16, 1893.*]

In 1857, Tuttle (*Annalen*, **101**, 285) studied the action of ammonia upon molybdenum trioxide, and molybdenum chloride ($MoCl_4$). In the case of the trioxide the temperature at which the reaction was made approached a red heat. The resulting product was in part black in color and possessed metallic lustre. Its analysis revealed the presence of nitrogen, oxygen, hydrogen and molybdenum. The quantity of the latter constituent equalled 92·9 per cent. Upon conductivity the reaction at more elevated temperatures, the product was found to contain 77·9 per cent. and 73 per cent. of molybdenum, while the hydrogen content did not exceed 0·18 per cent. The results consequently were not constant.

On exposing molybdenum chloride to the action of ammonia gas at a temperature just sufficient to volatilize the ammonium chloride which arose in the reaction, Tuttle obtained a black, metallic sintered mass. It was found to contain 82·83 per cent. of molybdenum and was assumed to have the composition expressed by the formula $Mo_2N_2 + Mo(NH_2)_2$, analogous to a compound of tungsten obtained in a similar manner by Wöhler (*Annalen*, **73**, 190).

Several years after the publication of the preceding investigation, Uhrlaub presented an inaugural thesis, entitled "Die Verbindungen einiger Metalle mit Stickstoff" (Goettingen, 1859), from which we collate the following interesting facts: In the action of ammonia gas in the cold upon molybdenum chloride much heat was evolved and a black colored product resulted; its analysis showed the presence of 76·457 per cent. of molybdenum, 23·134 per cent. of nitrogen and 0·677 per cent. of hydrogen. In subsequent experiment

Uhrlaub employed a more intense heat, thus hoping to eliminate the slightest hydrogen content, but this element continued to show itself in his various products, until on raising the tube in which the reaction took place to an intense red heat he obtained a compound that careful analysis gave a composition which may be expressed by the formula Mo_3N_2. In other words, a molybdenum nitride had been formed by acting upon the chloride of the metal with ammonia gas at a high temperature.

When Uhrlaub tried the action of ammonia upon molybdic acid at a gentle heat, he obtained "pseudomorphuen," as he designated them, bluish-black in color. Several were prepared; they varied much in composition. Uhrlaub attributes this variation to the different degrees of heat employed and to the length of time during which the heated molybdenum trioxide was exposed to the action of the gas.

The preceding facts indicate that the action of ammonia gas, either upon the trioxide or chloride, is not as simple as might be presumed. An amide that might well be expected in either case appears not to have been obtained by either Tuttle or Uhrlaub.*

We hope to reach this result by the action of ammonia gas upon molybdenyl chloride, in accordance with the equation

$$MoO_2Cl_2 + 4NH_3 = MoO_2(NH_2)_2 + 2NH_4Cl.$$

It will be noticed that we apply the term molybdenyl chloride to the compound generally called molybdenum dioxychloride. Our assumption of molybdenyl is based upon the terms sulphuryl, chromyl, etc., applied to compounds possessing a constitution similar to that of the dioxychloride of molybdenum MoO_2Cl_2, SO_2Cl_2, CrO_2Cl_2.

Preparation of Molybdenyl Chloride.—Of the various methods proposed for the formation of this derivative of molybdenum we discovered that the action of dry chlorine

---

* The primary object of these gentlemen seems to have been the preparation of molybdenum nitrides.

upon the dioxide of the metal yielded by far the most satisfactory product, both as to purity and quantity. At a very gentle heat the molybdenyl chloride forms rapidly and sublimes in feathery crystals. Schulze (*Jr. Prakt. Chemie*, **29** (N. F.), p. 440), in discussing the action of molybdic acid upon metallic chlorides, proposes this procedure for the object we had in view, but we failed to meet with success in our application of the method. The yield was not very abundant.

The crystalline molybdenyl chloride, prepared as described, was introduced into porcelain boats, and these placed in tubes of hard glass, through which we conducted a brisk current of well-dried ammonia gas. The molybdenyl chloride immediately assumed a deep-black color, much heat was evolved and copious fumes of ammonium chloride vapor were carried out of the tube. Considerable moisture also collected upon the anterior portion of the combustion tube. At last heat sufficient to expel any ammonium chloride retained by the compound was applied; but it was not for a longer period than half an hour. The boat and contents were cooled in ammonia gas. The product of the reaction was placed over sulphuric acid to absorb any retained gas; a portion of it was also washed with water, and the aqueous solution examined for chlorine, but this was not found present. In general appearance the product was metallic and black in color. Analyses were made of different preparations. The molybdenum content was determined by oxidizing weighed portions of material with dilute nitric acid, evaporating carefully to dryness, finally applying a gentle heat for a period of fifteen minutes.

The hydrogen was estimated by burning the material in a current of oxygen, and collecting the water that was produced in a weighed calcium chloride tube.

The nitrogen estimations were three in number; one of them was carried out by the method of Dumas, while the other two were made by the soda-lime process.

The oxygen was obtained by difference.

Our analytical results may be tabulated as follows:

Molybdenum Determination.

	MoO_3 found.		Mo Per Cent.
(1) 0·1047 gram substance taken, ...	0·1156 gr.	=	73·65
(2) 0·1006	0·1108 "	=	73·42
(3) 0·1004	0·1110 "	=	73·70
(4) 0·1028	0·1113 "	=	73·47
(5) 0·1017	0·1126 "	=	73·80

The mean molybdenum percentage of these five determinations is 73·61 per cent.

Hydrogen Determination.

	Water found.		H Per Cent.
0·2088 gram substance taken, ...	·0082 gr.	=	0·43

Nitrogen Determination.

	Pt. found.		N Per Cent.
(1) 0·1510 gram substance taken, ...	·0643 gr.	=	6·05
(2) 0·1529	·0642 "	=	5·96

The nitrogen found by the Dumas method equalled 6·00 per cent. and the mean of the three nitrogen estimations was also 6·00 per cent.

Two-thirds of this nitrogen content were expelled when our compound was exposed to the action of hydrogen at the highest temperature attainable with a good combustion furnace.

Taking the mean of our analyses as a basis of calculation:

	Per Cent.
Mo, ...	73·60
N, ...	6·00
H, ...	0·43
O (by difference), ...	19·96

we deduce $Mo_5O_8N_3H_3$ as the most probable empirical formula, which may be variously written to express the enigmatical constitution of this compound. Thus it might be $MoO(NH)_2$. MoONH. $3MoO_2$, or 4 MoO_2. $Mo(NH)_3$, which may be correctly termed tetramolybdenyl molylbdenimide.

Our compound is stable in the air. Hydrochloric acid does not affect it. Nitric acid of sp. gr. 1·42 causes it

to burn very energetically. Dilute alkalies attack it very sluggishly. It liberates ammonia when fused with caustic potash. When heated in a current of oxygen it is slowly oxidized. Heated in nitrogen gas the black compound loses water and assumes a reddish color. An analysis of this product indicates that it was probably molybdenum dioxide mixed with a very small amount of nitride; at least, traces of nitrogen were found upon examination. Another interesting observation was that when the black product was introduced into an aqueous solution of silver nitrate, crystals of metallic silver gradually appeared over the surface of the molybdenum compound.

We obtained our first product several times, but care must be exercised and the same conditions noted by us strictly observed if success in its formation is desired.

An examination of Uhrlaub's analytical results will show that one of his products approaches very closely the compound we have just described. He speaks of it as a black "pseudomorph" with the composition:

	Per Cent.
Mo,	73·55
N,	5·58
H,	0·54
O,	20·30

The formula deduced from these figures differs from that presented by us, and what is more, if we understand Uhrlaub correctly, his compounds, prepared from ammonia gas and molybdenum trioxide, were all "blau-schwarz" in color, and were not acted upon in the cold by nitric acid (see his dissertation, pp. 13, 14, 17).

However, it is evident that the product we obtained by the action of ammonia gas upon molybdenyl chloride is not the amide we had in view. Thinking that perhaps the heat we applied to drive out the final traces of occluded ammonium chloride may have been sufficient to alter the composition of the product formed at first, we allowed the ammonia to act upon the molybdenyl chloride at the ordinary temperature, and when there was no further evolution of ammonium chloride and the boat had become perfectly

cold* we introduced carbon dioxide, applying a very gentle heat at the same time, but we failed to achieve our aim. Nitrogen when substituted for carbon dioxide gave us no better result. We next dissolved molybdenyl chloride in the purest ether we could get and conducted ammonia gas into this solution. We obtained decomposition products. A closer examination of the behavior of the molybdenyl chloride towards ether revealed the fact that the moment the two came in contact a slight hissing sound was perceptible and the ether at once imparted a strong acid reaction to blue litmus. The same was observed when pure chloroform was employed as a solvent.

If molybdenyl chloride be gradually heated in an ammonia atmosphere until the tube of hard glass becomes bright red in color and the gas action be continued for the period of an hour, the resulting product will be an amorphous, metallic, black mass. Subjected to analysis it gave results as appended:

Molybdenum Determination.

	MoO_3 *found.*		*Mo. Per Cent.*
(1) 0·1042 gram substance taken, . . .	0·1061 gr.	=	67·87

Nitrogen Determination.

0·1025 gram substance burned with soda lime gave 7·00 per cent. N.

Hydrogen Determination.

0·1012 substance ignited in a current of oxygen gave ·0109 gram of water equal to 1·19 per cent. H.

	Per Cent.
Mo, ...	67·87
N, ...	7·00
H, ...	1·19
O (by difference), ...	23·94

The empirical formula deduced from these figures is $Mo_7O_{14}N_5H_{10}$, which can also be written

$$4MoO_2.2MoO_2(NH_2)_2.MoO_2NH_2$$

Dilute alkalies have no effect upon this compound; but

* Portions of the product removed at this stage and shaken with cold water decomposed into a mixture of blue- and brown-colored masses. The possibility of removing the ammonium chloride was, therefore, excluded.

it liberates ammonia when fused with caustic potash. It is converted into molybdenum trioxide very energetically—with evolution of sparks—when brought in contact with cold nitric acid.

Other products were obtained by us; their analyses lead us to the conclusion that with us as with Uhrlaub the composition of the derivative depended wholly upon the length of time during which the gas acted upon the molybdenyl chloride, and the degree of heat employed in the experiment. It seems highly improbable to us that the amide $MoO_2(NH_2)_2$—molybdenyl amide—can be prepared after the fashion pursued by us, for it is quite certain that the heat of the reaction evolved in the first contact of the ammonia with the molybdenyl chloride exercises a very potent influence upon the composition of the product.

When we recall the action of ammonia gas upon sulphur trioxide and sulphuryl hydroxy-chloride resulting in the compounds with the following constitution:

$$H_2N.SO_2\ OH$$

$$HN.\!<\!\begin{matrix} SO_2\ OH \\ SO_2.\ OH \end{matrix}$$

$$N\!\begin{cases} SO_2\ OH \\ SO_2.\ OH \\ SO_2\ OH \end{cases}$$

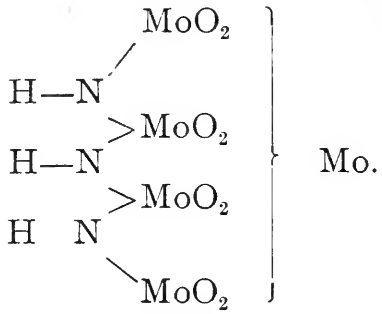
The question that obtrudes itself is: Are not these products and their methods of formation types of the processes and results that have occurred not only in our studies described in this paper, but also in the studies of Tuttle and Uhrlaub?* Are not their products as well as our own only residues of amide, imido, and nitrito molybdic acids?

Above we have written for our first product the constitutional formulæ $MoO(NH)_2.\ MoONH.\ 3MoO_2$, and $4MoO_2.\ Mo(NH)_3$, but after considering the sulphur types we would

---

* At least in so far as the action of ammonia gas upon molybdenum trioxide was concerned.

express our empirical formula $Mo_5O_8N_3H_3$ differently, as follows:



We have here several broken-down molybdenyl amide nuclei in conjunction, not chemically combined, with metallic molybdenum. Reviewing the behavior of the product which we thus graphically represent, we may be allowed to emphasize the fact that when it was brought in contact with an aqueous argentic nitrate solution metallic silver was precipitated, and this we know from Smith's* observation is a property of metallic molybdenum. Further, it will be recalled that when our product was heated in an atmosphere of nitrogen it left a reddish-colored compound, which upon analysis approximated the requirements of molybdenum dioxide, and that traces of nitrogen were also detected in it. All these experimental facts find expression in our graphic representation above.

The second product obtained by us was even more active when introduced into a silver nitrate solution, throwing out metal quite rapidly, proving in our opinion the presence in it of even a greater quantity of metallic molybdenum than is contained in the first body. Similar reduced molybdenyl amide nuclei mixed with metallic molybdenum, could also be constructed for our second compound, and be in harmony with the observed deportment of this body if it were necessary.

UNIVERSITY OF PENNSYLVANIA,
PHILADELPHIA, May 16, 1893.

---

* *Zeitschrift für anorg. Chemie*, **1**, 360.

GELATINOUS SILVER CYANIDE.

By Lee K. Frankel.

[*Read before the Chemical Section, June 20, 1893.*]

In the *Comptes Rendus*, **73**, 998, Stas has described the occurrence of four different varieties of silver chloride, viz:

(*a*) the gelatinous;
(*b*) the cheesy, flocculent;
(*c*) the pulverulent;
(*d*) the granular crystalline variety.

No methods are given for obtaining these varieties, nor could the author find any reference in the literature to any other salts of silver having the above properties. The following will, therefore, be of interest.

Recently the author instructed one of the students in the University laboratory to reduce silver chloride to metallic silver by fusion with potassium cyanide. As the work was purely experimental, no weighed quantities of the substances were taken, nor was any notice taken of the temperature at which the fusion took place. The cooled mass and porcelain crucible were placed in a beaker, covered with water, boiled for thirty minutes, and then put aside until the following day. On examining the contents of the beaker, instead of finding the liquid above the crucible clear, as had been expected, it was filled with a transparent gelatinous mass, somewhat resembling aluminum hydrate, but of greater consistency. A portion of this precipitate was removed from the solution, carefully washed with cold water until the filtrate reacted neither with silver nitrate nor with dilute hydrochloric acid, and then carefully dried.

A qualitative examination showed the following: The substance is readily soluble in ammonium hydroxide, from which solution it is re-precipitated by nitric acid. It does not fuse on heating, but decomposes readily, leaving a residue of metallic silver. The presence of cyanogen was readily detected by the "prussian blue" reaction. No chlorine was found.

A quantitative estimation of the silver in the substance gave a result which was five per cent. lower than the theoretical amount of silver in silver cyanide.

This is in all probability due to the impurities contained in the compound, which arise from the potassium cyanide used in its preparation.

The amount of substance used in the analysis was very small, since what appeared to be a rather large quantity of the original, moist, gelatinous compound, shrivelled to a very small bulk on drying.

Repeated attempts have since been made to procure more of the substance for analysis, but all efforts have so far been futile. The amounts of silver chloride and potassium cyanide used have been varied, and the fusion likewise has been made at different temperatures, but without success. It is the intention of the author to fuse silver cyanide with potassium cyanide, and thereby to obtain the desired result.

UNIVERSITY OF PENNSYLVANIA,
PHILADELPHIA, June 15, 1893.

THE ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, May 30, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 30, 1893.

ELMER G. WILLYOUNG, President, in the chair.

The Section's meeting of this date was called to order by President Willyoung, with an attendance of twenty members and visitors. The Treasurer reported a balance on hand of $17.09.

Mr. Willyoung reported that Prof. Elihu Thomson had written in response to the Section's invitation, that he was unable to appear at this time on account of prior engagements.

Mr. W. N. Jennings exhibited, by a projecting lantern, some lightning photographs. He first mentioned having shown before the Section, at its stated meeting of September 27, 1892, a number of these photographs, taken by him from a moving train, while crossing the prairies of North Dakota, being apparently single flashes, but giving multiple images of telegraph poles and

buildings. He stated that, at that time, from actual observation, he had come to the conclusion that lightning was a rapid oscillation or pulsation along a given path, and if the camera is moved during such a discharge, the resulting photograph would show a series of parallel lines, more or less numerous according to the rapidity of the camera movement. He now exhibited a photograph of a multiple flash of lightning taken from a moving train, the original flash appearing to the eye a single line of light, but in the photograph having even distinct lines, all having the same contour. He also showed a large "ribbon" flash of lightning, which effect, according to Tesla, Thomson, Young and others, was due to camera movement during the discharge. Mr. Jennings pointed out the fact that in the photograph, the telegraph poles, railroad ties and branches from the main stem of the discharge were all sharply defined, which led him to doubt the suggestion that the ribbon effect in this particular case was due to camera movement.

Mr. Thos. Spencer read a paper on "Some Interesting Peculiarities of Alternating Arc Lamps. It was referred for publication

The meeting then adjourned. ROBT. H. LAIRD, *Secretary.*

[*Proceedings of the stated meeting, held Tuesday, June 27, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 27, 1893.

ELMER G. WILLYOUNG, President, in the chair.

The stated meeting of the Section was called to order by President Willyoung, with an attendance of seventeen members and visitors.

Minutes of the previous meeting were read and approved. The Treasurer reported $36.09 on hand, and presented a bill for $3.20 for printing, which he was authorized to pay.

Mr. Paul A. Winand read a paper on "Rotary Magnetic Fields." It was referred for publication.

The President having been obliged to leave and neither of the Vice-Presidents being present, Mr. L. F. Rondinella was elected Chairman, *pro tem.*

It was moved that a vote of thanks be extended to the Secretary of the Institute for his courtesy in placing before the Section an exhibit of "Carborundum," and the data concerning some of its properties. The meeting then adjourned until September 26th. R. H. LAIRD, *Secretary.*

BOOK NOTICE.

Pumping Machinery. A practical hand-book relating to the construction and management of steam and power pumping machines. By William M. Barr. Philadelphia: J. B. Lippincott Company. 1893. pp. 447.

The scope of this work can be best described by the words of the author. The book is essentially descriptive of pump detail; no attempt has been made to enter into the theory and mathematics of pump construction. The volume has been prepared for the benefit of engineers, architects, contractors, etc., who have occasion to recommend and use pumping machinery, and who wish to inform themselves regarding pump construction. The book is divided into nineteen chapters, the first seven of which deal with the details of the design, the remainder treating of various classes of pumps and pumping engines, arranged according to the distinctive feature or special use to which they are applied.

Chapter I is used for introducing the subject generally, giving an idea of the various classes of pumps and data as to common practice in determining pressures for which the majority of pumps are made.

Chapter II treats of water pistons and plungers, giving clear sketches of the various forms in common use, the detail of making, securing and packing, and covering pistons, practically all forms of pumps in every-day use.

Chapter III treats of pistons and plunger rods, the material of which they should be made, the sizes in common use, the methods of securing them to the piston and of packing them.

Chapter IV treats of water valves and seats, the variation of pressure between the two sides of a valve, the materials of which valves are made, the method of securing them in place, of guiding them, of reducing the lift, and, in fact, of all the details that one not engaged in pump-making would be likely to inquire about.

Chapter V treats of air chambers. Chapter VI, of suction and delivery pipes, and Chapter VII of the design of the water end. The remaining chapter of the book treats of hydraulic pressure pumps, steam and power crank pumps, the duplex pump, compound direct-acting steam pumps, fire pumps, mining pumps, rotary pumps, centrifugal pumps, duty trials of pumping engines, direct-acting and fly-wheel high-duty pumping engines.

The book closes with an admirable index, making the work highly valuable for reference.

The amount of detail in this book is something unusual, and one reading it simply for general information fears to skip a page, as he might thereby lose a portion of the very interesting matter, of which the book is full. The name of the author above should be sufficient warrant that nothing but what was of permanent value would be found between its covers, and a careful reading convinces one that Mr. Barr has produced one of the most interesting and valuable works we have in English on an engineering specialty.

H. W. S.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXVI. SEPTEMBER, 1893. No. 3

ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA.*

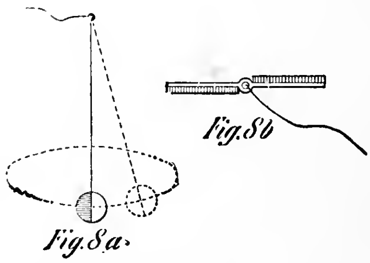
BY NIKOLA TESLA.

[*Continued from p. 98.*]

When a conducting body is immersed in air, or similar insulating medium, consisting of, or containing, small freely movable particles capable of being electrified, and when the electrification of the body is made to undergo a very rapid change—which is equivalent to saying that the electrostatic force acting around the body is varying in intensity—the small particles are attracted and repelled, and their violent impacts against the body may cause a mechanical motion of the latter. Phenomena of this kind are note-

* A lecture delivered before the Franklin Institute, at Philadelphia, February 24, 1893, and before the National Electric Light Association, at St. Louis, March 1, 1893.

worthy inasmuch as they have not been observed before with apparatus such as has been commonly in use. If a very light conducting sphere be suspended on an exceedingly fine wire, and charged to a steady potential, however high, the sphere will remain at rest. Even if the potential be rapidly varying, provided that the small particles of matter, molecules or atoms, are evenly distributed, no motion of the sphere should result. But if one side of the conducting sphere is covered with a thick insulating layer, the impacts of the particles will cause the sphere to move about, generally in irregular curves, *Fig. 8a.* In like manner, as I have shown on a previous occasion, a fan of metal sheet, *Fig. 8b*, covered partially with insulating material as indicated, and placed upon the terminal of the coil so as to turn freely in it, is caused to spin around.



Mechanical motions produced by varying electrostatic force in a gaseous medium.

All these phenomena you have witnessed and others which will be shown later, are due to the presence of a medium like air, and would not occur in a continuous medium. The action of the air may be illustrated still better by the following experiment. I take a glass tube *t*, *Fig. 9*, of about an inch in diameter, which has a platinum wire *w* sealed in the lower end, and to which is attached a thin lamp filament *f*. I connect the wire with the terminal of the coil and set the coil to work. The platinum wire is now electrified positively and negatively in rapid succession, and the wire and air inside of the tube are rapidly heated by the impacts of the particles, which may be so violent as to render the filament incandescent. But if I pour oil in the tube, just as soon as the wire is covered with the oil, all action apparently ceases and there is no marked evidence

of heating. The reason of this is that the oil is a practically continuous medium. The displacements in such a continuous medium are, with these frequencies, to all appearance incomparably smaller than in air, hence the work performed in such a medium is insignificant. But oil would behave very differently with frequencies many times as great, for even though the displacements be small, if the frequency were much greater considerable work might be performed in the oil.

The electrostatic attractions and repulsions between bodies of measurable dimensions are, of all the manifestations of this force, the first so-called *electrical* phenomena noted. But though they have been known to us for many

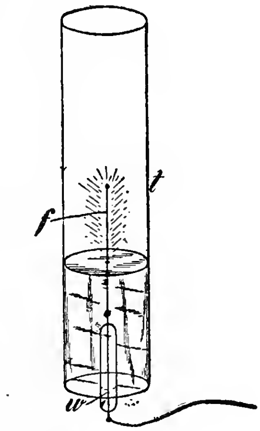


Fig. 9

Showing the effect of the air.

centuries, the precise nature of the mechanism concerned in these actions is still unknown to us, and has not even been quite satisfactorily explained. What kind of mechanism must that be? We cannot help wondering when we observe two magnets attracting and repelling each other with a force of hundreds of pounds with apparently nothing between them. We have in our commercial dynamos magnets capable of sustaining in mid-air tons of weight. But what are even these forces acting between magnets when compared with the tremendous attractions and repulsions produced by electrostatic force, to which there is apparently no limit as to intensity. In lightning discharges, bodies are often charged to so high a potential that they

are thrown away with inconceivable force and torn asunder or shattered into fragments. Still even such effects cannot compare with the attractions and repulsions which exist between charged molecules or atoms, and which are sufficient to project them with speeds of many kilometres a second, so that under their violent impact bodies are rendered highly incandescent and are volatilized. It is of special interest for the thinker who inquires into the nature of these forces to note, that whereas the actions between individual molecules or atoms occur seemingly under any conditions, the attractions and repulsions of bodies of measurable dimensions imply a medium possessing insulating properties. So, if air, either by being rarefied or heated, is

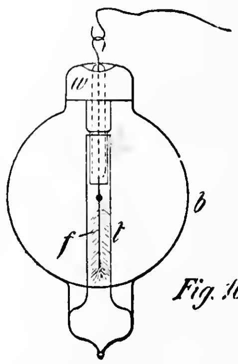


Fig. 10

Showing the influence of the conductivity of the medium upon electrostatic actions through measurable distance.

rendered more or less conducting, these actions between two electrified bodies practically cease, while the actions between the individual atoms continue to manifest themselves.

An experiment may serve as an illustration and as a means of bringing out other features of interest. Some time ago I showed that a lamp filament or wire mounted in a bulb and connected to one of the terminals of a high tension secondary coil is set spinning, the top of the filament generally describing a circle. This vibration was very energetic when the air in the bulb was at ordinary pressure, and became less energetic when the air in the bulb was strongly compressed. It ceased altogether when the air was exhausted so as to become a comparatively good con-

ductor. I found at that time that no vibration took place when the bulb was very highly exhausted. But I conjectured that the vibration which I ascribed to the electrostatic action between the walls of the bulb and the filament should take place also in a highly exhausted bulb. To test this under conditions which were more favorable, a bulb, like the one in *Fig. 10*, was constructed. It comprised a globe *b*, in the neck of which was sealed a platinum wire *w*, carrying a thin lamp filament *f*. In the lower part of the globe a tube *t*, was sealed so as to surround the filament. The exhaustion was carried as far as practicable with the apparatus employed.

This bulb verified my expectation, for the filament was set spinning when the current was turned on, and became incandescent. It also showed another interesting feature, bearing upon the preceding remarks; namely, when the filament had been kept incandescent some time the narrow tube and the space inside was brought to an elevated temperature, and as the gas in the tube then became conducting, the electrostatic attraction between the glass and the filament became very weak or ceased and the filament came to rest. When it came to rest it would glow far more intensely. This was probably due to its assuming the position in the centre of the tube where the molecular bombardment was most intense, and also partly to the fact that the individual impacts were more violent and that no part of the supplied energy was converted into mechanical movement. Since, in accordance with accepted views, in this experiment the incandescence must be attributed to the impacts of the particles, molecules or atoms, in the heated space, these particles must, therefore, in order to explain such action, be assumed to behave as independent carriers of electric charges immersed in an insulating medium; yet there is no attractive force between the glass tube and the filament because the space in the tube is, as a whole, conducting.

It is of some interest to observe, at this point, that whereas the attraction between two electrified bodies may cease owing to the impairing of the insulating power of the

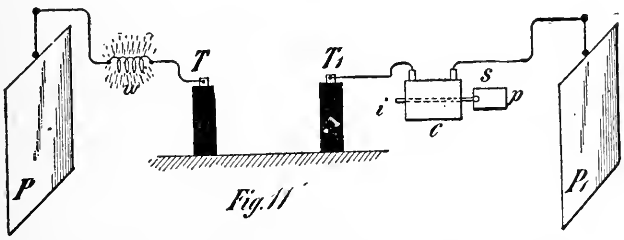
medium in which they are immersed, the repulsion between the bodies may still be observed. This may be explained in a plausible way. When the bodies are placed at some distance apart in a poorly conducting medium, such as slightly warmed or rarefied air, and are suddenly electrified, opposite electric charges being imparted to them, these charges are equalized more or less by leakage through the air. But if the bodies are similarly electrified, less opportunity is afforded for such dissipation, hence the repulsion observed in such case is greater than the attraction. Repulsive action in a gaseous medium is, however, as Professor Crookes has shown, enhanced by molecular bombardment.

On Current or Dynamic Electricity Phenomena.—So far, I have considered principally effects produced by a varying electrostatic force in an insulating medium, such as air. When such a force is acting upon a conducting body of measurable dimensions, it causes within the same, or on its surface, displacements of the electricity and gives rise to electric currents, and these produce another kind of phenomena, some of which I shall presently endeavor to illustrate. In presenting this second class of electrical effects, I will avail myself principally of such as are producible without any return circuit, hoping to interest you the more by presenting these phenomena in a more or less novel aspect.

It has been for a long time customary, owing to the limited experience with vibratory currents, to consider an electric current as something circulating in a closed conducting path. It was astonishing at first to realize that a current may flow through the conducting path even if the latter be interrupted, and it was still more surprising to learn, that sometimes it may even be easier to make a current flow under such conditions than through a closed path. But that old idea is gradually disappearing, even among practical men, and will soon be entirely forgotten.

If I connect, by means of a wire, an insulated metal plate *P*, *Fig. 11*, to one of the terminals *T*, of the induction coil though this plate be very well insulated, a current passes through the wire when the coil is set to work. First, I wish

to give you evidence that there is a current passing through the connecting wire. An obvious way of demonstrating this is to insert between the terminal of the coil and the insulated plate a very thin platinum or German-silver wire *w*, and bring the latter to incandescence, or fusion, by the current. This requires a rather large plate or else current impulses of very high potential and frequency. Another way is to take a coil *C*, *Fig. 11*, containing many turns of thin insulated wire and to insert the same in the path of the current to the plate. When I connect one of the ends of the coil to the wire leading to another insulated plate P_1 and its other end to the terminal T_1 of the induction coil, and set the latter to work, a current passes through the inserted coil *C*, and the existence of the current may be made manifest in various ways. For instance, I insert an iron core *i*



Showing effects of currents flowing through open circuits.

within the coil. The current being one of the very high frequency, will, if it be of some strength, soon bring the iron core to a noticeably higher temperature, as the hysteresis and current losses are great with such high frequencies.

One might take a core of some size, laminated or not, it would matter little; but ordinary iron wire one-sixteenth or one-eighth of an inch thick is suitable for the purpose. While the induction coil is working, a current traverses the inserted coil and only a few moments are sufficient to bring the iron wire *i*, to an elevated temperature sufficient to soften the sealing wax *s*, and cause a paper washer *p*, fastened by it to the iron wire to fall off. But with the apparatus, such as I have here, other much more interesting demonstrations of this kind can be made. I have a secondary *S*, *Fig. 12*, of coarse wire wound upon a coil similar to the first. In the preceding experiment the

current through the coil *C*, *Fig. 11*, was very small, but there being many turns, a strong, heating effect was, nevertheless, produced in the iron wire. Had I passed that current through a conductor in order to show the heating of the latter, the current might have been too small to produce the effect desired. But with this coil provided with a secondary winding, I can now transform the feeble current of high tension which passes through the primary *P*, into a strong secondary current of low tension, and this current will certainly do what I expect. In a small glass tube (*t*, *Fig. 12*), I have enclosed a coiled platinum wire *w*, merely in order to protect the wire. On each end of the glass tube is sealed a terminal of stout wire, to which one of the ends of the platinum wire *w* is connected. I join the terminals of the secondary coil to these terminals and insert the primary *p*, between the insulated plate P_1 and the

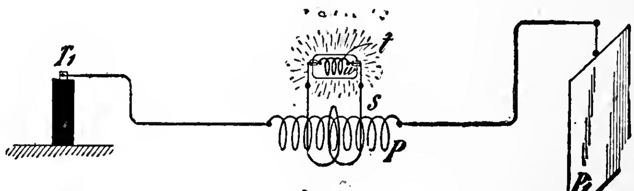


Fig. 12

Conversion on open circuit with coil and insulated plate.

terminal T_1 of the induction coil, as before. The latter being set to work, the platinum wire *w*, is instantly rendered incandescent and can be fused even if it be very thick.

Instead of the platinum wire I now take an ordinary fifty-volt sixteen candle-power lamp. When I set the induction coil in operation, the lamp filament is brought to high incandescence. It is, however, not necessary to use the insulated plate, for the lamp (*l*, *Fig. 13*) is rendered incandescent even if the plate P_1 be disconnected. The secondary may also be connected to the primary as indicated by the dotted line in *Fig. 13*, to do away more or less with the electrostatic induction, or to modify the action otherwise.

I may here call attention to a number of interesting observations with the lamp. First, I disconnect one of the terminals of the lamp from the secondary *S*. When the induction coil plays, a glow is noted which fills the whole

bulb. This glow is due to electrostatic induction. It increases when the bulb is grasped with the hand, and the capacity of the experimenter's body thus added to the secondary circuit. The secondary, in effect, is equivalent to a metallic coating, which would be placed near the primary. If the secondary, or its equivalent, the coating, were placed symmetrically to the primary, the electrostatic induction would be *nil* under ordinary conditions; that is, when a primary return circuit is used, as both halves would neutralize each other. The secondary *is* in fact placed symmetrically to the primary, but the action of both halves of the latter, when only one of its ends is connected to the induction coil, is not exactly equal; hence, electrostatic induction takes place, and hence the glow in the bulb. I

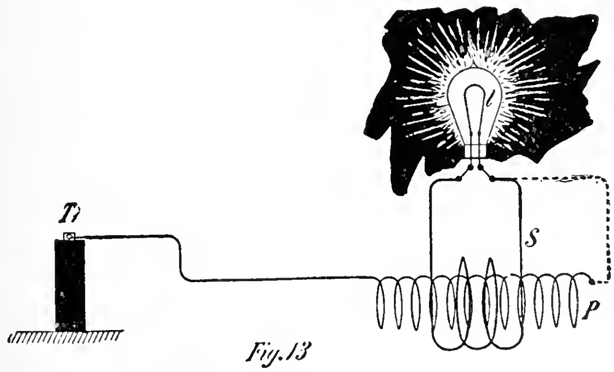


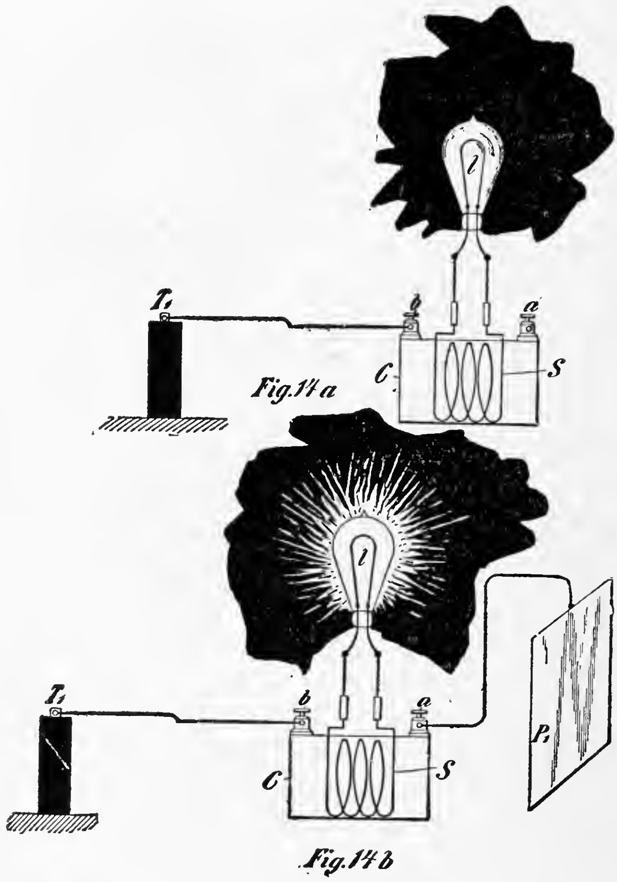
Fig. 13

Conversion on open circuit with coil alone.

can nearly equalize the action of both halves of the primary by connecting the other, free, end of the same to the insulated plate, as in the preceding experiment. When the plate is connected, the glow disappears. With a smaller plate it would not entirely disappear, and then it would contribute to the brightness of the filament when the secondary is closed, by warming the air in the bulb.

To demonstrate another interesting feature, I have adjusted the coils used in a certain way. I first connect both the terminals of the lamp to the secondary, one end of the primary being connected to the terminal T_1, of the induction coil and the other to the insulated plate P_1, as before. When the current is turned on, the lamp glows brightly, as shown in *Fig. 14b*, in which C is a fine wire coil

and S a coarse wire secondary wound upon it. If the insulated plate P_1 be disconnected, leaving one of the ends a of the primary insulated, the filament becomes dark or generally it diminishes in brightness (*Fig. 14a*). Connecting again the plate P_1, and raising the frequency of the current I make the filament quite dark or barely red (*Fig. 15b*). Once more I will disconnect the plate. One will of course infer that when the plate is disconnected, the current



Effect of attached plate with low frequencies.

through the primary will be weakened, that, therefore, the E. M. F. will fall in the secondary S, and that the brightness of the lamp will diminish. This might be the case and the result can be secured by an easy adjustment of the coils; also by varying the frequency and potential of the currents. But it is perhaps of greater interest to note, that the lamp increases in brightness when the plate is disconnected (*Fig. 15a*). In this case all the energy the primary receives

is now sunk into it, like the charge of a battery in an ocean cable, but most of that energy is recovered through the secondary and used to light the lamp. The current traversing the primary is strongest at the end *b*, which is connected to the terminal T_1, of the induction coil, and diminishes in strength toward the remote end *a*. But the dynamic inductive effect exerted upon the secondary *S* is now greater than before when the suspended plate was

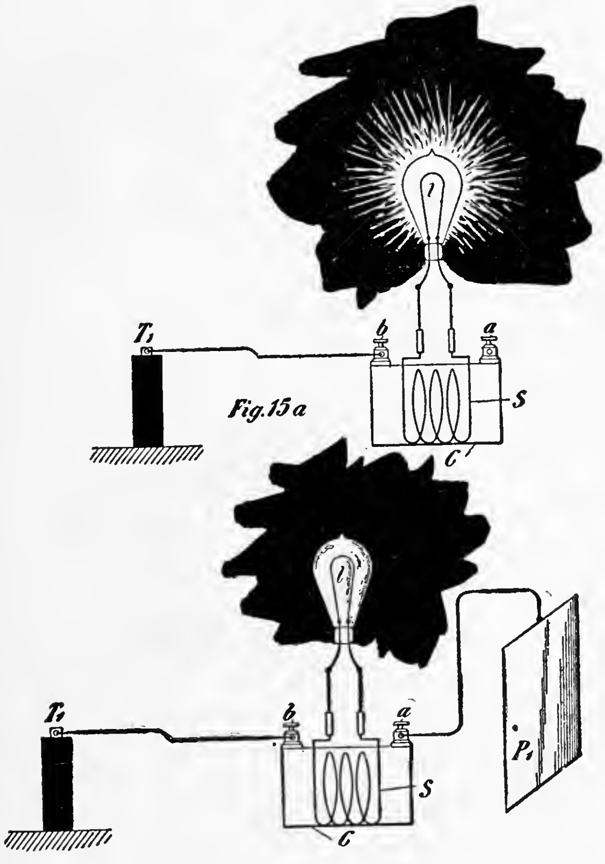


Fig. 15 b

Effect of attached plate with high frequencies.

connected to the primary. These results might have been produced by a number of causes. For instance, the plate P_1, being connected, the reaction from the coil *C*, may be such as to diminish the potential at the terminal T_1, of the induction coil, and therefore weaken the current through the primary of the coil *C*. Or, the disconnecting of the plate may diminish the capacity effect with relation to the primary of the latter coil, to such an extent that the current

through it is diminished, though the potential at the terminal T_1, of the induction coil may be the same or even higher. Or, the result might have been produced by the change of phase of the primary and secondary currents and consequent reaction. But the chief determining factor is the relation of the self-induction and capacity of coil C and plate P_1, and the frequency of the currents. The greater brightness of the filament in *Fig. 15a* is, however, in part due to the heating of the rarefied gas in the lamp by electrostatic induction, which as before remarked, is greater when the suspended plate is disconnected.

Still another feature of some interest I may here bring to your attention. When the insulated plate is disconnected and the secondary of the coil opened, by approaching a small object to the secondary, only very small sparks can be drawn from it, showing that in this case the electrostatic induction is small. But upon the secondary being closed upon itself, or through the lamp, the filament glowing brightly strong sparks are obtained from the secondary. The electrostatic induction is now much greater, because the closed secondary determines a greater flow of current through the primary and principally through that half of it which is connected to the induction coil. If now the bulb be grasped with the hand, the capacity of the secondary with reference to the primary is augmented by the experimenter's body and the luminosity of the filament is increased, the incandescence now being due partly to the flow of current through the filament, and partly to the molecular bombardment of the rarefied gas in the bulb.

The preceding experiments will have prepared one for the next following results of interest, obtained in the course of these investigations. Since I can pass a current through an insulated wire merely by connecting one of its ends to the source of electrical energy; since I can induce by it another current, magnetize an iron core, and in short, perform all operations, as though a return circuit were used, clearly I can also drive a motor by the aid of only one wire. On a former occasion I described a simple form of motor comprising a single exciting coil, an iron core and

disc. *Fig. 16* illustrates a modified way of operating such an alternate current motor by currents induced in a transformer connected to one lead, and several other arrangements of circuits for operating a certain class of alternate motors founded on the action of currents of differing phase. In view of the present state of the art it is thought sufficient to describe these arrangements in a few words only. The diagram, *Fig. 16II*, shows a primary coil *P*, connected by one of its ends to the line *L*, leading from a high tension transformer terminal T_1. In inductive relation to this primary *P*, is a secondary *S*, of coarse wire in the circuit of which is a coil *c*. The currents induced in the secondary energize the iron core *i*, which is preferably, but not necessarily, subdivided, and set the metal disc *d*, in rotation. Such a motor M_2, as diagramatically shown in *Fig. 16II*, has been called a "magnetic lag motor," but this expression may be objected to by those who attribute the rotation of the disc to eddy currents circulating in minute paths when the core *i* is finally subdivided. In order to operate such a motor effectively on the plan indicated, the frequencies should not be too high, not more than 4,000 or 5,000, though the rotation is produced even with 10,000 per second, or more.

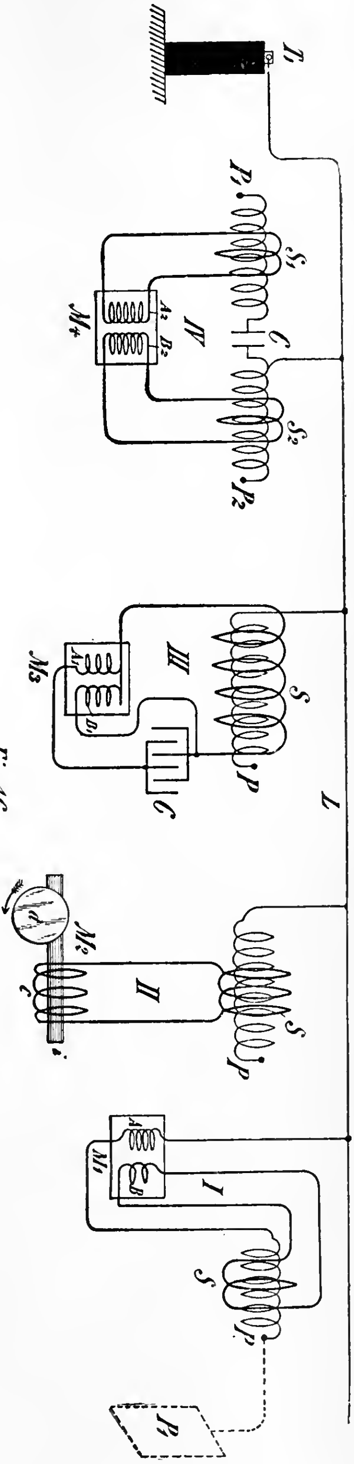


Fig. 16

Ways of operating motors with only one lead.

In *Fig. 16I*, a motor M_1, having two energizing circuits, *A* and *B*, is diagrammatically indicated. The circuit *A* is

connected to the line L, and in series with it is a primary P, which may have its free end connected to an insulated plate P_1, such connection being indicated by the dotted lines. The other motor circuit B is connected to the secondary S, which is in inductive relation to the primary P. When the transformer terminal T_1 is alternately electrified, currents traverse the open line L and also circuit A and primary P. The currents through the latter induce secondary currents in the circuit S, which pass through the energizing coil B of the motor. The currents through the secondary S, and those through the primary P, differ in phase 90°, or nearly so, and are capable of rotating an armature placed in inductive relation to the circuits A and B.

In *Fig. 16III*, a similar motor M_3, with two energizing circuits, A_1 and B_1, is illustrated. A primary P, connected with one of its ends to the line L, has a secondary S, which is preferably wound for a tolerably high E. M. F., and to which the two energizing circuits of the motor are connected, one directly to the ends of the secondary and the other through a condenser C, by the action of which the currents traversing the circuit A_1 and B_1 are made to differ in phase.

In *Fig. 16IV*, still another arrangement is shown. In this case two primaries P_1 and P_2 are connected to the line L, one through a condenser C of small capacity, and the other directly. The primaries are provided with secondaries S_1 and S_2, which are in series with the energizing circuits A_2 and B_2, and a motor M_3, the condenser C again serving to produce the requisite difference in the phase of the currents traversing the motor circuits. As such phase motors with two or more circuits are now well-known in the art, they have been here illustrated diagrammatically. No difficulty whatever is found in operating a motor in the manner indicated or in similar ways, and although such experiments up to this day present only scientific interest, they may at a period not far distant, be carried out with practical objects in view.

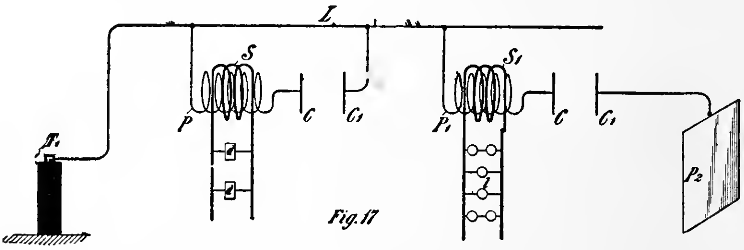
It is thought useful to devote here a few remarks to the subject of operating devices of all kinds by means of only

one leading wire. It is quite obvious, that when high frequency currents are made use of, ground connections are —at least when the E. M. F. of the currents is great—better than a return wire. Such ground connections are objectionable with steady or low frequency currents on account of destructive chemical actions of the former and disturbing influences exerted by both on the neighboring circuits; but with high frequencies these actions practically do not exist. Still, even ground connections become superfluous when the E. M. F. is very high, for soon a condition is reached, when the current may be passed more economically through open than through closed conductors. Remote as might seem an industrial application of such single wire transmission of energy to one not experienced in such lines of experiment, it will not seem so to any one who for some time has carried on investigations of such nature. Indeed, I cannot see why such a plan should not be practicable. Nor should it be thought that for carrying out such a plan currents of very high frequency are necessarily required, for just as soon as potentials of (say) 30,000 volts are used, the single wire transmission may be effected with low frequencies, and experiments have been made by me from which these inferences are made.

When the frequencies are very high it has been found in laboratory practice quite easy to regulate the effects in the manner shown in diagram, *Fig. 17*. Here two primaries P and P are shown, each connected with one of its ends to the line L, and with the other end to the condenser plates C and C', respectively. Near these are placed other condenser plates C_1 and C'_1, the former being connected to the line L and the latter to an insulated larger plate P_2. On the primaries are wound secondaries S and S_1, of coarse wire, connected to the devices m and d, respectively. By varying the distances of the condenser plates C and C', and C_1, and C'_1, the currents through the secondaries S and S_1 are varied in intensity. The curious feature is the great sensitiveness, the slighest change in the distance of the plates producing considerable variations in the intensity or strength of the currents. The sensitiveness may be

rendered extreme by making the frequency such, that the primary itself without any plate attached to its free end satisfies, in conjunction with the closed secondary, the condition of resonance. In such condition an extremely small change in the capacity of the free terminal produces great variations. For instance, I have been able to adjust the conditions so that the mere approach of a person to the coil produces a considerable change in the brightness of the lamps attached to the secondary. Such observations and experiments possess, of course, at present, chiefly scientific interest, but they may soon become of practical importance.

Very high frequencies are, of course, not practicable with motors on account of the necessity of employing iron cores. But one may use sudden discharges of low frequency and thus obtain certain advantages of high frequency currents



Single wire conversion and distribution, with simple means for regulating the effects.

without rendering the iron core entirely incapable of following the changes and without entailing a very great expenditure of energy in the core. I have found it quite practicable to operate alternating current motors with such low frequency disruptive discharges of condensers. A certain class of such motors which I described a few years ago, which contain closed secondary circuits will rotate quite vigorously when the discharges are directed through the exciting coils. One reason that such a motor operates so well with these discharges is that the difference of phase between the primary and secondary currents is 90°, which is generally not the case with harmonically rising and falling currents of low frequency. It may not be without interest to show an experiment with a simple motor of this kind, inasmuch as it is commonly thought that disruptive discharges are unsuitable for such purposes. The motor is

illustrated in *Fig. 18*. It comprises a rather large iron core *i*, with slots on the top into which are embedded thick copper washers *c c*. In proximity to the core is a freely movable metal disc *D*. The core is provided with a primary exciting coil *C*, the ends *a* and *b*, of which are connected to the terminals of the secondary *s* of an ordinary transformer, the primary *P*, of the latter being connected to an alternating distribution circuit, or generator *G*, of low or moderate frequency. The terminals of the secondary *s* are attached to a condenser *C*, which discharges through an air gap *d d*, which may be placed in series or shunt to the coil *C*. When the conditions are properly chosen, the disc *D* rotates with considerable effort and the iron core *i* does not get very perceptibly hot. With currents from a high frequency alternator, on the contrary, the core gets rapidly hot and

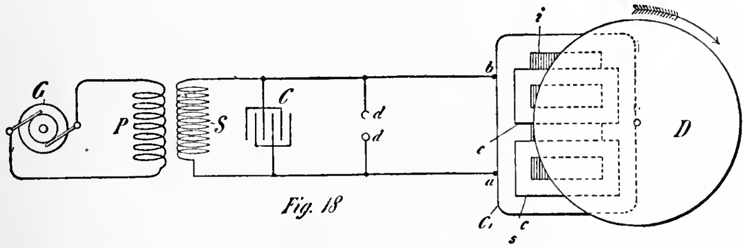


Fig. 18

Operating a motor by disruptive discharges.

the disc rotates with a much smaller effort. To perform the experiment properly it should be first ascertained that the disc *D* is not set in rotation when the discharge is not occurring at *d d*. It is preferable to use a large iron core and a condenser of large capacity, so as to bring the superimposed quicker oscillation to a very low pitch or to do away with it entirely. By observing certain elementary rules I have also found it practicable to operate ordinary series, or shunt direct current motors, with such disruptive discharges, and this can be done with or without a return wire.

[*To be continued.*]

The SPECIFIC HEATS of the METALS.

By Jos. W. Richards, Ph.D.,
Instructor in Metallurgy, etc., in Lehigh University.

[*A lecture delivered before the Franklin Institute, January 30, 1893.*]

[*Concluded from p. 131.*]

Kopp obtained results from iron, the average of eight experiments at 15° to 60° being 0·1120. His minimum value was 0·108, and maximum 0·114, showing here especially the roughness of his experiments and the general unreliability of his results, although the mean, in this case, comes very near the probably true value.

Naccari made experiments similar to Byström's, arriving at the formulæ:

$$S = 0{\cdot}1072 + 0{\cdot}000116\,t + 0{\cdot}0000001466\,t^2$$

$$Sm = 0{\cdot}1072 + 0{\cdot}000058\,t + 0{\cdot}0000000489\,t^2$$

The diagram shows clearly the relative position of Naccari's results.

Pionchon experimented up to 1,150° with the soft iron of "Berry," which contained no manganese or phosphorus, and only a trace of carbon and silicon. Pionchon found two points at which heat was rendered latent, about 5·3 calories being absorbed between 660° and 720°, and 6·0 calories between 1,000° and 1,050°. He gives the following formulæ for the mean specific heat from temperatures within the designated limits to zero:

$$(0° \text{ to } 660°)\ Sm = 0{\cdot}11012 + 0{\cdot}000025\,t + 0{\cdot}0000000547\,t^2$$

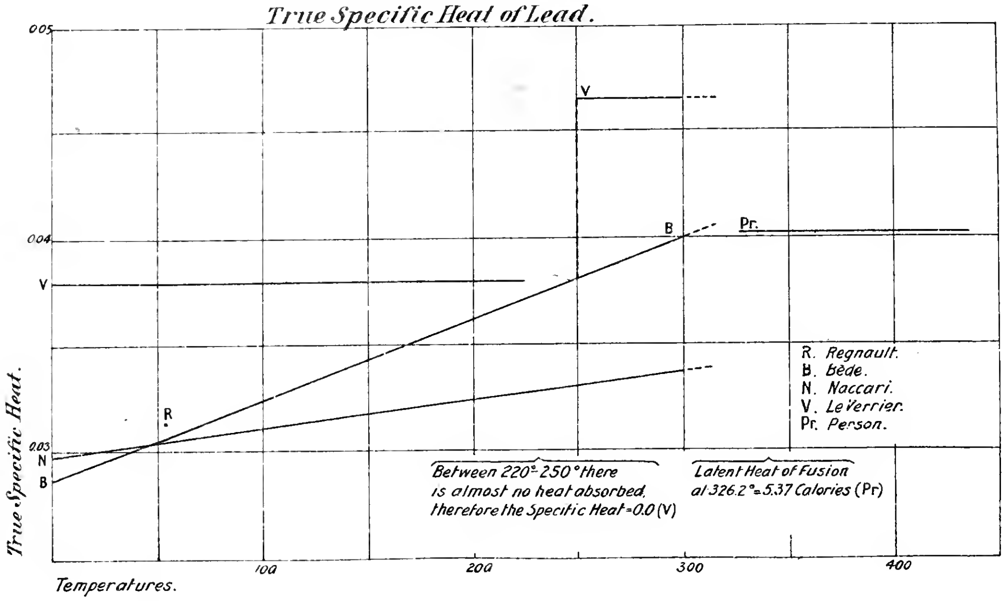
$$(660° \text{ to } 720°)\ Sm = 0{\cdot}57803 - 0{\cdot}001436\,t + 0{\cdot}000001195\,t^2$$

$$(720° \text{ to } 1{,}000°)\ Sm = 0{\cdot}218 - \frac{39}{t}$$

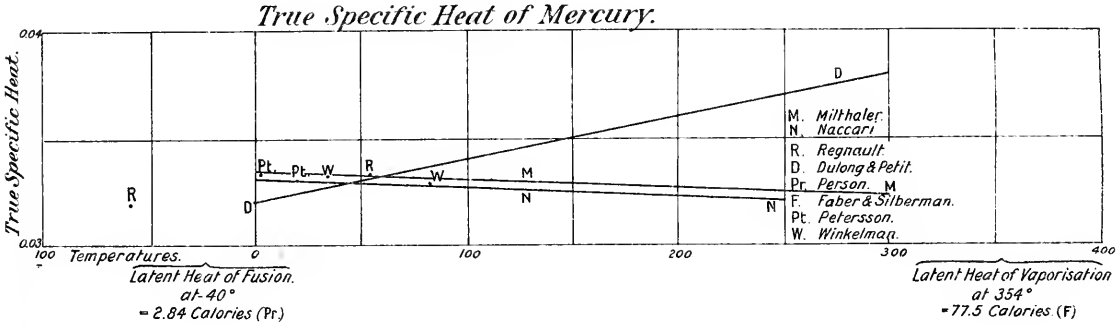
$$(1{,}050° \text{ to } 1{,}160°)\ Sm = 0{\cdot}19887 - \frac{23{\cdot}44}{t}$$

It will be seen that the first formula is of the same nature as the preceding ones, the subsequent ones are complicated

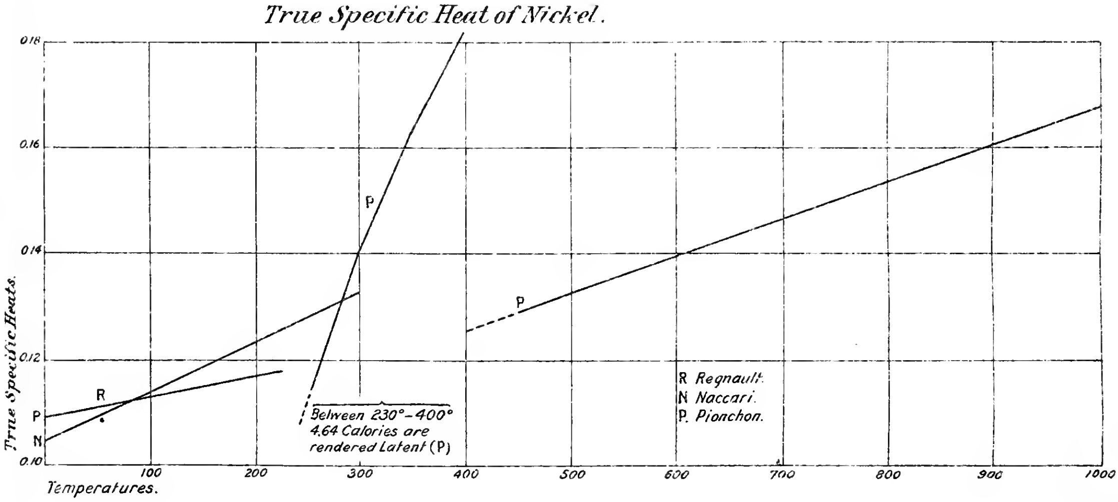
True Specific Heat of Lead.



True Specific Heat of Mercury.



True Specific Heat of Nickel.



by having to include the heat rendered latent. The values of the true specific heat at any temperature are best seen by reference to the diagram. It increases gradually up to the first critical point, after which it remains constantly 0·218 until the second critical point is reached, after which it is again constant at 0·1989.

Pionchon remarks that these critical points coincide with sudden changes in the magnetic and conductive properties of iron, and also calls attention to the fact that from 720° to 1,000° the specific heat is almost exactly double what it is at zero.

The presence of carbon and silicon in iron increases its specific heat, so that steel and cast iron are superior to pure iron in calorific capacity. The study of these bodies is therefore of interest, but can only be referred to briefly here. Regnault found the specific heat of cast steel (Haussman's) 0·11848, cast iron 0·12728, white iron 0·12983. Byström found that of cast steel 0·11850, and of pig iron 0·1283, and also found the variations of these with the temperature up to 300°, for a full statement of which the reader is referred to his orginal paper.

LANTHANUM.

Dr. Hillebrand found 0·04485, using metal containing 4·6 per cent. of didymium, 1·2 per cent. of iron, 0·3 per cent. of silicon and a little aluminum, and calculating the allowance for these impurities.

LEAD.

Wilcke found 0·042; Crawford, 0·0352; Kirwan, 0·05; Dalton, 0·04, and Dulong and Petit, 0·0293; the last two by the method of cooling.

Regnault gives 0·03140 (15°–98°).

Bède deduced from his experiments up to 200° the formula:

$$Sm = 0{\cdot}0286 + 0{\cdot}000019\,t$$

This evaluated for Regnault's range gives 0·03075, two per cent. below Regnault's value.

Kopp obtained 0·0308, 0·0302, 0·0293 and 0·0302; mean 0·0301 (15°–60°). Bède's formula gives for this range 0·0300.

Person found the specific heat of molten lead (335°–430°) 0·0402.

Naccari experimented to 300°, and deduced the formulæ:

$$S \;\; = 0{\cdot}02972 + 0{\cdot}0000136\,t$$

$$Sm = 0{\cdot}02972 + 0{\cdot}0000068\,t$$

This gives for Regnault's temperatures 0·03049, even a little below Bède.

Le Verrier finally states that the specific heat of lead is constantly 0·038 between 0° and 230°, that between 220° and 250° it is almost zero, for the metal absorbs almost no heat in transversing this interval of temperature, and between 250° and 300°, the specific heat is constantly 0·0465. These results are so unexpected and differ at ordinary temperatures so greatly from Regnault's value (twenty-two per cent. difference), that we must conclude that they are quite improbable.

It is seen that there is some uncertainty as to the specific heat of lead at ordinary temperatures. On examining the diagram, it is seen that Bède's value for the specific heat increases until near the melting point it is very nearly that observed by Person in the molten state. Now, since it has been observed in other metals that the specific heat in the solid state, near the melting point, approaches the specific heat in the molten state, the writer is disposed to consider Bède's and Person's results as corroborating each other. I would, therefore, modify Bède's formula by using Regnault's value as affecting the constant, and write as the probably correct formulæ for lead:

$$Sm = 0\;02925 + 0{\cdot}000019\,t$$

$$S \;\; = 0\;02925 + 0{\cdot}000038\,t$$

This curve will pass through Regnault's value, and have the rate of increase determined by Bède.

Latent Heat of Fusion.—Dr. Irvine, Jr., determined that the latent heat would raise the temperature of an equal weight of solid lead at the melting point 162° F., and, using Crawford's value for the specific heat, this equals 5·6 calories Fahrenheit or 3·1 Centigrade. If we use the value given by

the above formula, 0·042415, his determination would give the latent heat as 3·8 calories.

Rudberg worked by the method of cooling also, and assuming that solid lead at its melting point had a specific heat of 0·0352, he obtained 5·858 calories as the latent heat. If we use 0·042415 instead of 0·0352, the latent heat would become 7·058.

Person found molten lead at its melting point to give out 15·61 calories. Assuming Regnault's value to be constant to the melting point, he obtained 5·37 calories as the latent heat. Had he used Bède's formula he would have obtained 4·27 calories, or with Naccari's formula 5·18 calories, or Bède's corrected formula 3·94. Or using the *total* amount of heat in solid lead at its melting point as found by Le Verrier (11·68 calories), the latent heat would be 3·93.

I think the best conclusion to be drawn from this discussion is that the latent heat of fusion of lead is about this latter figure, 3·95 calories.

LITHIUM.

Regnault gives 0·941 at 20°–98°.

MAGNESIUM.

Regnault found 0·25 (22°–98°); Kopp obtained results varying between 0·240 and 0·249, mean 0·245 (15°–55°).

MANGANESE.

Regnault first found 0·1441 (14°–98°), but remarked that the metal was impure. Afterwards he obtained 0·1330 with a specimen which showed important quantities of carbon and silicon. Still later he found 0·122 (12°–98°) for a specimen containing still a little silicon.

MERCURY.

Crawford found 0·0357; Leslie, 0·0290, and Kirwan, 0·033. Dulong and Petit found 0·033 (0°–100°) and 0·035 (0°–300°), giving the formula

$$Sm = 0{\cdot}0320 + 0{\cdot}00001\ t$$

Regnault found 0·03332 (12°–98°), and 0·0319 at 59°, in the solid state.

Winkelman found 0·03312 (20°–50°), and 0·03278 (25°–142°). This last result would indicate a decrease in the specific heat with rise of temperature, and lead to the formula

$$S = 0·0336 - 0·0000069\ t$$

Pettersson found

0° to — 5°,	0·033266
— 5° to — 16°,	0·033262
— 5° to — 26°,	0·033300
— 5° to — 36°,	0·033299

Naccari has recently determined the following values for the true specific heat:

0°,	0·03337
50°,	0·03310
100°,	0·03284
150°,	0·03259
200°,	0·03235
250°,	0·03212

These data show a regularly *decreasing* specific heat, and lead to the formulæ

$$S = 0·03337 - 0·0000055\ t + 0·000000002\ t^2$$
$$Sm = 0·03337 - 0·00000275\ t + 0·00000000667\ t^2$$

It will be noticed that Naccari's figures agree well with those of Winkelman, giving for 20°–50°, 0·03322, and for 25°–142°, 0·03309. Naccari's formula gives for Regnault's temperatures (12°–98°) 0·03314, which is only 0·5 per cent. different.

Milthaler has found as the mean of his experiments the formula

$$S = S_0 (1 - 0·000138\ t)$$

If S_0 (the true specific heat at zero) be taken as 0·033266 (Pettersson's value) the formula becomes

$$S = 0·033266 - 0·0000046\ t$$

Or, if Naccari's value for S_0 is taken

$$S = 0·03337 - 0·0000046\ t$$

Or, if Regnault's value for S at 60° is taken

$$S = 0·033596 - 0·00000461\ t$$

If Pettersson's results are reliable, they show that the specific heat of mercury between 0° and 36° is practically

constant. The most recent experiments agree in showing that above 0° the specific heat decreases with the temperature.

Kundt and Warburg have determined the specific heat of vapor of mercury, which is found to be 0·1714 at constant pressure and 0·102843 at constant volume. Since these quantities are to each other in the proportion 5 : 3, it follows from the mechanical theory of heat that the molecule of mercury must consist of only one atom; a conclusion which agrees with that deduced from the density of mercury vapor, thus confirming in a remarkable manner one of the deductions from Clausius' theories.

Latent Heat of Fusion and Vaporization.—Person found the latent heat of fusion by reversing the method of cooling, as 2·84 calories. Fabre and Silberman found the latent heat of vaporization in an indirect way by means of iodine vapor as 77·5 calories.

MOLYBDENUM.

Regnault found 0·07218 (12°–98°), but the specimen contained an undetermined amount of carbon.

De la Rive and Marcet found 0·0659 at ordinary temperatures by the method of cooling.

NICKEL.

Dalton found 0·10 and Dulong 0·1035, both by the method of cooling.

Regnault found 0·10863 (13°–99°).

Pionchon investigated up to 1,050°. He found a gradual increase in the specific heat up to 230°, but between that and 400° a very rapid increase, but after 400° the former rate resumed. He, therefore, concluded that between those two temperatures there is a gradual change of state, which would represent the absorption of 4·64 calories as latent heat. The diagram shows this break clearly. Pionchon gives the following formulæ for the mean specific heat to zero from any temperature within the designated limits.

Between	0° and	230°	$Sm = 0{\cdot}10836 + 0{\cdot}00002233\, t$
	230° "	400°	$Sm = 0{\cdot}183493 - 0{\cdot}000282\, t + 0{\cdot}000000467\, t^2$
	440° "	1,050°	$Sm = 0{\cdot}099 + 0{\cdot}00003375\, t + \frac{6{\cdot}55}{t}$

Pionchon remarks that this change of state corresponds to known variations in nickel's magnetic and conducting properties.

Naccari experimented up to 320°, and deduces the formulæ:

$$S \quad = 0{\cdot}1043 + 0{\cdot}0000946\ t$$

$$Sm = 0{\cdot}1043 + 0{\cdot}0000473\ t$$

Naccari remarks that all tests showed this metal to be pure, and that as far as he went he found no trace of the phenomenon mentioned by Pionchon.

OSMIUM.

Regnault found 0·0311 (22°–98°).

PALLADIUM.

Regnault gives 0·05928 (11°–98°).

Violle investigated it up to 1,265°, and found results agreeing to the formula:

$$Sm = 0{\cdot}0582 + 0{\cdot}000010\ t$$

This formula gives for Regnault's range 0·05929, a remarkable coincidence.

The amount of heat in solid palladium as near as possible to its melting point was found to be 109·8 calories, which, according to the above equation, would indicate a maximum fusing point of 1,500°.

Latent Heat of Fusion.—Three experiments to find the heat in molten palladium at its setting point gave 146·0, 145·8, and 146·4 calories, respectively, mean 146·1. Subtracting from this the heat in solid palladium at that temperature leaves 36·3 calories as the latent heat of fusion.

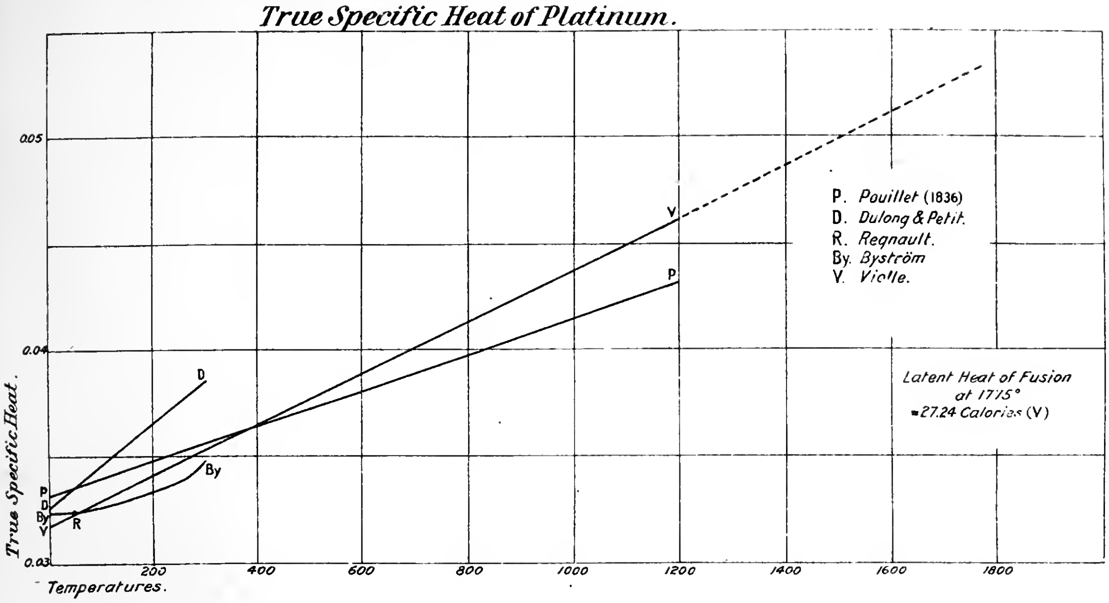
PLATINUM.

Dr. Irvine found 0·03, and Dulong and Petit 0·0314 by the method of cooling.

Dulong and Petit found 0·0335 (0°–100°) and 0·0355 (0°–300°), which lead to the formula

$$Sm = 0{\cdot}0325 + 0{\cdot}00001\ t$$

Pouillet made a careful study of platinum in 1836, using


True Specific Heat of Platinum.
P. Pouillet (1836)
D. Dulong & Petit.
R. Regnault.
By. Byström
V. Violle.
Latent Heat of Fusion at 1715° = 27.24 Calories (V)
True Specific Heat.
Temperatures.
0.05
0.04
0.03
200
400
600
800
1000
1200
1400
1600
1800

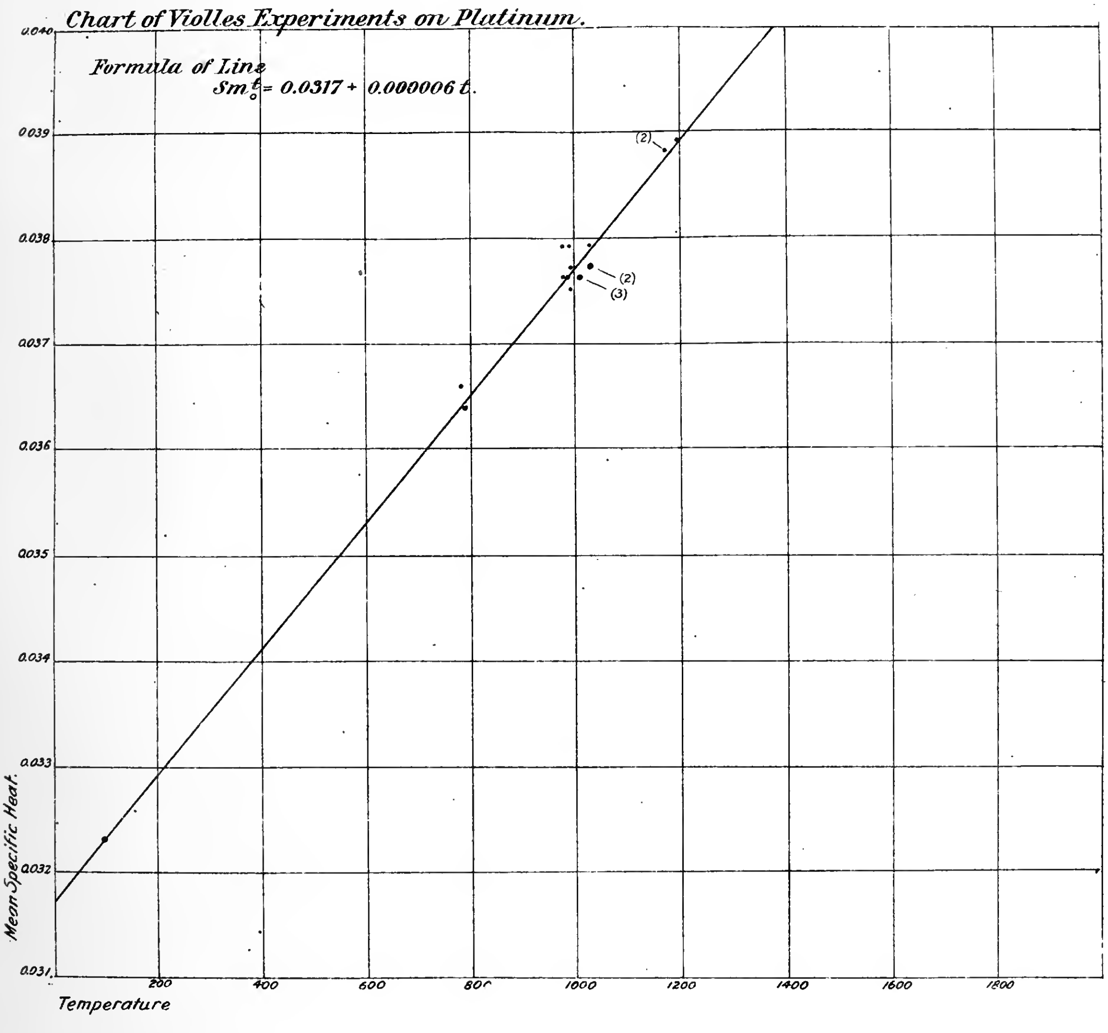


Chart of Violles Experiments on Platinum.
Formula of Line
$Sm_0^t = 0.0317 + 0.000006\,t$.
Mean Specific Heat.
Temperature
0.040
0.039
0.038
0.037
0.036
0.035
0.034
0.033
0.032
0.031
200
400
600
1000
1200
1400
1600
1800

the air thermometer up to 1,200°. The data which he gives lead to the formulæ:

$$Sm = 0\cdot03308 + 0\cdot0000042\ t$$

$$S = 0\cdot03308 + 0\cdot0000084\ t$$

Regnault found 0·03243 (12°–99°).

Byström obtained rather anomalous results. He found that up to 250° the rate of increase was uniform, according to the formulæ:

$$S = 0\cdot032386 + 0\cdot00000094\ t + 0\cdot000000188\ t^2$$

$$Sm = 0\cdot032386 + 0\cdot00000047\ t + 0\cdot0000000627\ t^2$$

Above 250° Byström observed a very sudden rise, which no other observer has noted. The formula would give the true specific heat at 300°, 0·034360, while Byström records 0·034750, a sudden rise of 1·2 per cent. above the curve which fits all his lower results.

Kopp obtained results varying from 0·0316 to 0·0335 (15°–60°), so that his observations are of no interest in comparisons of accurate data.

Weinhold also investigated platinum, but his results vary so greatly among themselves as to be worthless.

Violle has made a most careful study of platinum up to 1,200°. He remarks that Pouillet's observations were in error chiefly because he used a platinum bulb for his air thermometer, which gives erroneous results because of transfusion of gases through the platinum at high temperatures. Violle used a porcelain bulb, and all the precautions possible to take in such experiments. Since these determinations and formulæ are so greatly relied on in using platinum as a pyrometer, I have considered it important that Violle's results should be thoroughly understood. The diagram of Violle's results shows the particular values found by him for the mean specific heat to zero, and their proximity to the line which he chooses as best representing his results. The greatest difference between his experiments was about 1·1 per cent. at any given temperature, the greatest deviation from the assumed mean line 0·8 per cent.

$$Sm = 0\cdot0317 + 0\cdot000006\ t$$

Violle found by direct experiment Sm (0°–100°) 0·0323. which would become 0·0324 for Regnault's range of temperatures, results practically identical. We must regard Violle's results as being altogether the best we possess for platinum.

Latent Heat of Fusion.—Violle made five determinations of the heat in solid platinum as near to its melting point as possible, the mean value obtained being 75·21 calories to zero. (By the formula this would indicate a maximum point of fusion of 1,775°.) Four experiments were made on the heat in molten metal at its setting point, the mean value obtained being 102·39 calories to 0°. From these data the latent heat of fusion is 27·18 calories.

POTASSIUM.

Regnault found 0·1660 between — 78° and + 10°.

RHODIUM.

A specimen containing iridium gave Regnault 0·0553 (12°–98°); another purer specimen 0·0580.

RUTHENIUM.

Bunsen found 0·0611 (0°–100°).

SILVER.

Wilcke gave 0·082; Dalton, 0·08.

Dulong and Petit found 0·0557 (0°–100°) and 0·0611 (0°–300°), which would give the formula of two terms.

$$Sm = 0{\cdot}0530 + 0{\cdot}000027\,t$$

Regnault obtained 0·05701 (14°–99°), almost two per cent. higher than given by the above formula.

Byström investigated up to 300° and gives his results calculated for the true specific heats at every 50° up to 300°. His figures are represented by the equations

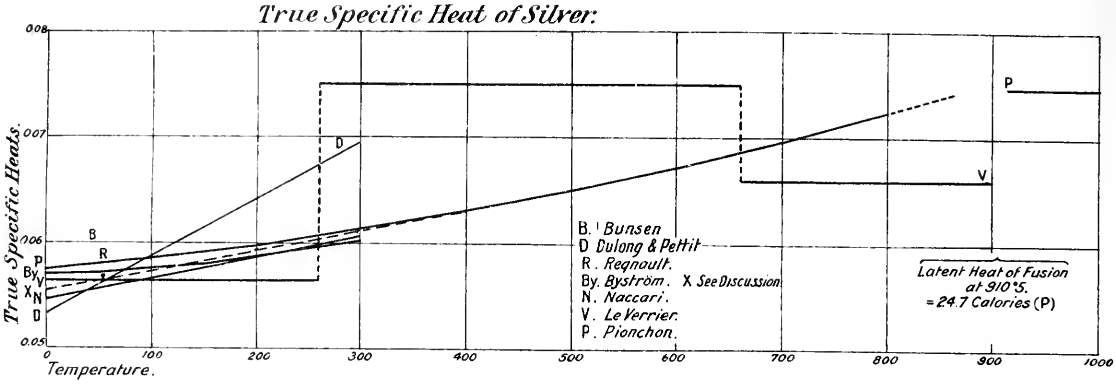
$$S = 0{\cdot}05698 + 0{\cdot}0000023\,t + 0{\cdot}000000032\,t^2$$

$$Sm = 0{\cdot}05698 + 0{\cdot}00000115\,t + 0{\cdot}0000000107\,t^2$$

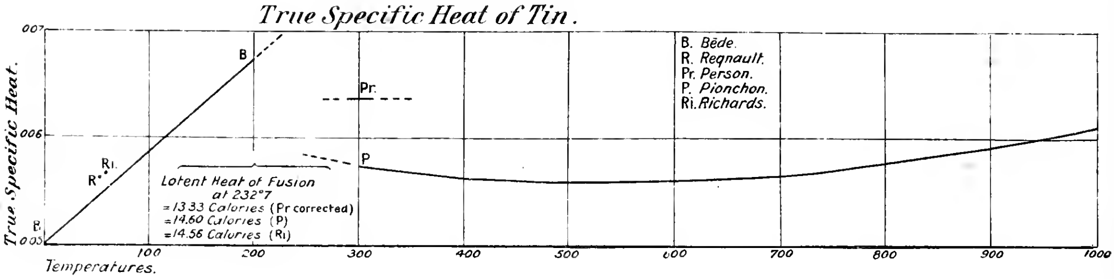
This equation would give for Regnault's temperatures 0·05725, about identical with Regnault's value.

Kopp obtained values varying from 0·0552 to 0·0574, mean 0·0560 (15°–65°).

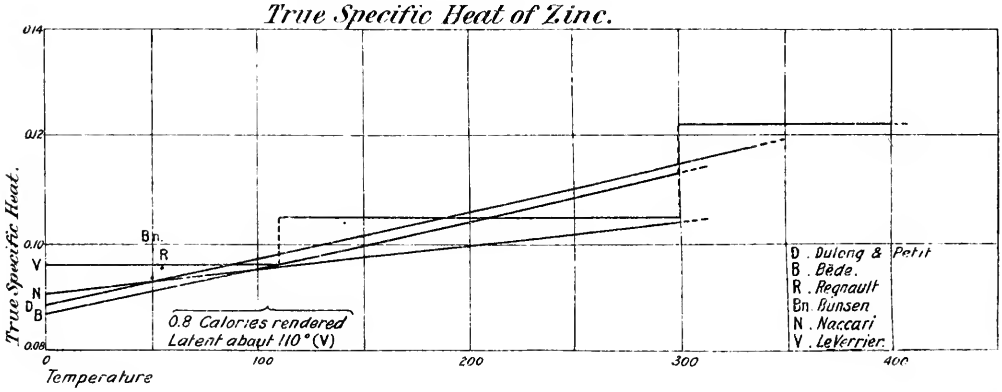
True Specific Heat of Silver.



True Specific Heat of Tin.



True Specific Heat of Zinc.



Bunsen obtained 0·0559 (0°–100°), a value almost identical with Dulong and Petit's.

Pionchon investigated up to 1,020°. He found up to the melting point a regular formula of three terms, viz:

$$Sm = 0·05758 + 0·0000044\, t + 0·000000006\, t^2$$

This equation gives for Regnault's range of temperature 0·05815, which is two per cent. above his value. In the molten state, Pionchon found the following formula for the mean specific heat to zero:

$$Sm = 0·0748 + \frac{17·20}{t}$$

the true specific heat in this condition being constantly 0·0748. The formula for the solid state would give its true specific heat at the melting point as 0·075; we thus have another example of the specific heat in the solid state approaching equality to that in the liquid state as the melting point is approached.

Naccari's experiments up to 300° led to the following formulæ:

$$S = 0·05449 + 0·0000214\, t$$

$$Sm = 0·05449 + 0·0000107\, t$$

The latter, evaluated for Regnault's temperatures, gives 0·0557, which is almost identical with Dulong and Petit's value.

Le Verrier claims that the specific heat is constant up to 260°, then changes suddenly and is again constant up to 660°, then changes again and is constant to the melting point. He gives between 0° and 260°, 0·0565; between 260° and 660°, 0·075, between 660° and 900°, 0·066. As no other observer has observed any such sudden changes, it is probable that Le Verrier is mistaken in his results. Le Verrier states that silver contains sixty-two calories of heat towards 930°, a little before the fusion. Pionchon places the fusing point at 907°, and gives 60·32 calories as the amount of heat in the metal at this temperature.

It is difficult to decide just where the truth lies in this case of the specific heat of silver. If it were allowable to do so, an average of all the results at ordinary tempera-

tures would come close to Regnault's value. But, since Pionchon made no experiments below 400°, I should be disposed to place less reliance on his values for temperatures from 0° to 100°. I would suggest for use below 400°, a formula based on the mean of Regnault's and Bunsen's observations at 0° to 100° and on Pionchon's result at 0° to 400°. Such a formula would be

$$S = 0{\cdot}0555 + 0{\cdot}00001886\, t$$

$$Sm = 0{\cdot}0555 + 0{\cdot}00000943\, t$$

This gives for Bunsen's range 0·05644, for Regnault's range 0·0566, being in each case about one per cent. from their figures. At 220°, the point where it will be seen from the diagram that the lines of Byström and Naccari meet, at the value for S of 0·0590, the above formula gives 0·0596. At 400° the line joins in with Pionchon's curve, and above 400° Pionchon's formula may be assumed as probably accurate. The curve proposed above is given as a dotted line on the diagram.

Latent Heat of Fusion.—Person determined this by the method of cooling to be 21·07 calories. Pionchon's formula for solid silver evaluated for the melting point gives 60·32, and his formula for liquid silver evaluated for that temperature gives 85·04, the difference between these would therefore be the latent heat of fusion, or 24·72 calories. Pionchon's number is probably the nearest right.

SODIUM.

Regnault obtained 0·293 (38° to + 10°).

THALLIUM.

Regnault obtained 0·0335 (18°–98°).

THORIUM.

Nilson obtained 0·0276 (0°–100°).

TIN.

Crawford found 0·0704; Wilcke, 0·06, and Kirwan, 0·068. Dalton obtained 0·07 by the method of cooling.

Dulong and Petit obtained 0·0514 by the method of cooling.

Regnault found for impure English tin 0·05695 (16°–97°), and for pure Banca tin 0·05623 (14°–99°).

Bède obtained results up to 213°, from which he deduced the formula:

$$Sm = 0{\cdot}0500 + 0{\cdot}000044\,t$$

This evaluated for Regnault's temperatures gives 0·0550, over two per cent. lower.

Kopp obtained results varying between 0·0493 and 0·0553, mean 0·0531 (15°–65°) a result of very little value. A second set of experiments gave him results between 0·0543 and 0·0573, mean 0·0565. The mean of the two sets of experiments is 0·0548; but, the highest and lowest values he obtained were 16 per cent. apart!

Person found the specific heat of molten tin to be 0·0637, (250°–340°).

Bunsen found for *allotropic* tin 0·0545 (0°–100°) and for cast tin 0·0559 (0°–100°).

Pionchon found for molten tin up to 1,000° the formula:

$$Sm\ (\text{to } 0^\circ) = 0{\cdot}0612931 - 0{\cdot}0000104741\,t + 0{\cdot}0000000103448\,t^2 + \frac{14{\cdot}375}{t}$$

The writer has determined for Banca tin between 15° and 99°, 0·0566, a value 0·7 per cent. above Regnault's.

Latent Heat of Fusion.—Dr. Irvine, Sr., working under Dr. Black, found that the latent heat would raise the temperature of solid tin 500° F. (at what temperature not stated). Dr. Irvine, Jr., found in a similar way 507°, the mean between 495° and 520°. In reaching these results, the heat in molten tin at its setting point was first found. This was divided by the ordinary specific heat of tin, and the melting point subtracted. This would be equivalent to assuming that the heat in solid tin at its melting point is the product of that temperature into the ordinary specific heat. Since we do not know what value Irvine assumed for the latter we cannot correct his figures. If he used Crawford's value 0·0704, his result would represent about 18·3 calories; if he had used 0·0570, his results would have been 16 calories.

Rudberg worked by the method of cooling, and assuming that the specific heat of solid tin at its melting point is

0·0586, he obtained 13·31 calories as the latent heat of fusion. If we assume that the specific heat at this temperature is the same as Person found for molten tin (0·0637), Rudberg's results would become 14·46 calories.

Person found the amount of heat in molten tin at its setting point to be 27·33 calories. Then, assuming that Regnault's value for the specific heat was applicable to the melting point, he found the heat in solid tin at its melting point to be $232·7 \times 0·05623 = 13·08$ calories, which left 14·25 calories as the latent heat of fusion. Had he used the amount found by Bède in solid tin, at its melting point, by direct experiment, he would have had $27·33 - 13·60 = 13·73$ calories as the latent heat.

Pionchon's formula for liquid tin evaluated for the melting point gives 28·20 calories. Subtracting Bède's value for the heat in solid tin leaves 14·60 calories as the latent heat.

Direct experiment, by pouring liquid tin just at its melting point into water, has given the writer 28·16 calories. This, less 13·60, would leave 14·56 calories as the latent heat of fusion. The close agreement of this result with Pionchon's is worthy of notice, especially since the heat in the molten tin was determined by two entirely different methods of procedure.

TITANIUM.

Nilson and Pettersson determined the mean specific heat as follows:

0° to 100°,	0·1125
0° to 211°,	0·1288
0° to 301°·5,	0·1485
0° to 404°,	0·1620

These would give the formula

$$Sm = 0·0978 + 0·000147\ t$$

This formula fits almost exactly the first, second and last of the above observations, but gives 0·1421 for the third. A regular curve could not be found passing through all four of those values.

TUNGSTEN.

Regnault gives 0·03636 (11°–99°).

URANIUM.

Blümcke found 0·02811, 0·02762, 0·02813, mean 0·0280 (0°–99°). Zimmerman found on two specimens as a mean value 0·0275 and 0·2812 (0°–99°).

ZINC.

Wilcke found 0·102; Crawford, 0·0943, and Dalton, 0·10.

Dulong and Petit found 0·0927 (0°–100°) and 0·1015 (0°–300°). These results would give the formula:

$$Sm = 0{\cdot}0883 + 0{\cdot}000044\ t$$

Neumann obtained 0·0929, at ordinary temperatures, by the method of cooling.

Regnault obtained with commercial zinc 0·09985, 0·10049, 0·100003, and with chemically pure zinc 0·09555 (14°–99°).

Bède deduces from his experiments the formula

$$Sm = 0{\cdot}0865 + 0{\cdot}000044\ t$$

He observes that his metal contained a little lead.

Dulong and Petit's result is three per cent., and Bède's four per cent. below Regnault's.

Kopp obtained results varying between 0·0899 and 0·0977, mean 0·0932 (15°–65°).

Bunsen obtained 0·0935 (0°–100°).

Naccari deduces from his experiments up to 320° the formula:

$$S = 0{\cdot}0907 + 0{\cdot}000044\ t$$

This gives 0·0932 for Regnault's temperatures.

Le Verrier states that from 0° to 110° the specific heat of zinc is constantly 0·096; between 110° and 140° it is very variable, there being an absorption of 0·8 calorie about 110°; that from this point to 300° the specific heat is constantly 0·105, and between 300° and 400° constantly 0·122. The total amount of heat is about 46 calories at about 410°, a trifle before fusion.

Latent Heat of Fusion.—Dr. Irvine, assuming the specific heat of zinc constant to the fusing point (0·0943) found by experiment 62·5 calories in molten zinc, and subtracting the heat in solid zinc at its melting point (388°·9 × ·0943), he

obtained 62·5 — 35·7 = 26·8 calories as the latent heat. (I have transferred his Fahrenheit degrees to Centigrade.)

Person obtained an average of 67·81 calories in molten zinc at its setting point, and assuming Regnault's value for the specific heat true to the melting point, he found the latent heat to be 67·81 — (415·3 × 0·09555) = 67·81 — 39·68 = 28·13 calories. However, we know that this latter assumption is incorrect.

Supposing we take for the mean specific heat a line which would pass through Regnault's result and be parallel to Dulong and Petit's and Bède's lines, which are parallel to each other. Such a line would be

$$Sm = 0{\cdot}09058 + 0{\cdot}000044\ t$$

Now, Dulong and Petit's formula would give for the heat in solid zinc at its melting point 44·2 calories, Bède's 43·5 calories, and Naccari's 40·4 calories. The above formula gives 45·2 calories. It is noticeable that when Le Verrier gives the total heat in any metal close to its melting point, his value is usually near to the best determinations. He says there is about forty-six calories in zinc just below its melting point. I should, therefore, take the value 45·2 given by the above equation as probably the nearest right.

Irvine's result will now become 62·5 — 45·2 = 17·3 calories. Person's result, 67·81 — 45·2 = 22·61 calories. Person's is, of course, the better determination of the two.

ZIRCONIUM.

Mixter and Dana have obtained 0·0662 (0°-100°) with the ice calorimeter.

LITERATURE OF THE SPECIFIC HEATS OF THE METALS.

Black: Elements of Chemistry. Edinburgh, 1803, vol. 1, p. 137.

Lavoisier: Mémories de l'Académie des Sciences, 1780, p. 355. Œuvres Lavoisier, t. II, p. 283.

Wilcke: Journal de Physique, 1785, vol. 26, pp. 256, 381.

Irvine: Gilbert's Annalen, 1811, vol. 38, p. 305.

Dulong and Petit: Annales de chimie et de Physique, 1818, vol. 7, p. 142; 1819, vol. 10, p. 395. Journal de l'École Polytechnique, 1820, vol. 18, p. 189.

Rudberg: Poggendorff's Annalen, 1830, vol. 19, p. 125.
Neumann: Poggendorff's Annalen, 1831, vol. 23, p. 1.
Avogadro: Annales de Chimie et de Physique, 1834, vol. 55, p. 80; vol. 57, p. 113.
Pouillet: Comptes Rendus de l'Académie, 1836, vol. 3, p. 782.
Regnault: Annales de Chimie et de Physique, 1840, vol. 3, p. 5; 1841, vol. 1, pp. 129, 202, 1129; 1843, vol. 9, p. 322; 1849, vol. 26, p. 261; 1853, vol. 38, p. 129; 1856, vol. 46, p. 257; 1861, vol. 63, pp. 5, 24; 1862, vol. 67, p. 427; 1866, vol. 7, p. 450.
De la Rive and Marcet: Poggendorff's Annalen, 1841, vol. 52, p. 120.
Person: Annales de Chimie et de Physique, 1847, vol. 21, p. 327; vol. 24, pp. 136, 157, 265, 276.
Bède: Mémories de l'Académie de Bruxelles, 1855, vol. 25. Fortschritte der Physik, 1855, vol. 11, p. 379.
Byström: Fortschritte der Physik, 1860, vol. 16, p. 369.
Kopp: Liebig's Annalen, 1863, vol. 126, p. 362; Supplement Band, 1864, No. 3, vol. 1, p. 289; Philosophical Transactions, 1865.
Bettendorf and Wüllner: Poggendorff's Annalen, 1868, vol. 123, p. 293.
Bunsen: Poggendorff's Annalen, 1870, vol. 141, p. 1.
Weinhold: Poggendorff's Annalen, 1873, vol. 149, pp. 186, 215.
Mixter and Dana: Liebig's Annalen, 1873, vol. 169, p. 388.
Hildebrand: Poggendorff's Annalen, 1876, vol. 158, p. 71.
Winkelmann: Poggendorff's Annalen, 1876, vol. 159, p. 152.
Violle: Comptes Rendus, 1877, vol. 85, p. 543; 1878, vol. 87, p. 981; 1879, vol. 89, p. 702.
Berthelot: Annales de Chimie et de Physique, 1878, vol. 15, p. 242.
Kundt and Warburg: Poggendorff's Annalen, 1876, vol. 157, p. 353.
Nilson and Pettersson: Berliner Berichte, 1878, vol. 13, pp. 1451, 1784. Zeitschrift für Physikalische Chemie, 1887, vol. 1, p. 27.
Pettersson: Journal für Praktische Chemie, 1881, vol. 24, p. 146.
Zimmermann: Berliner Berichte, 1882, p. 847.
Hempidge: Proceedings Royal Society of London, 1885, vol. 39, p. 1.
Blümcke: Poggendorff's Annalen, 1875, vol. 24, p. 263.
Pebal and Jahn: Poggendorff's Annalen, 1886, vol. 27, p. 584.
Pionchon: Annales de Chimie et de Physique, 1887, vol. 11, p. 33; Comptes Rendus de l'Académie, 1892, vol. 115, p. 163.
Naccari: Memoires della R. Acad. di Torino, Dec., 1887; July, 1888; Beiblätter zu Wiedemann's Annalen, 1888, vol. 12, p. 848.
Milthaler: Wiedemann's Annalen, 1889, vol. 36, p. 897.
Mendeléeff: Principles of Chemistry, English Trans., vol. 1, p. 579.
Richards: Journal of the Franklin Institute, Feb., 1892; July–Sept., 1893.
Le Verrier: Comptes Rendus de l'Académie, 1892, vol. 114, p. 907.

CARBORUNDUM: ITS HISTORY, MANUFACTURE AND USES.

BY E. G. ACHESON.

[*Read at the stated meeting of the Institute, held June 21, 1893.*]

For a number of years prior to 1890, I had been keeping a constant watch for anything that might suggest a method by which carbon could be crystallized. A realization of the importance of abrasive materials, in the industrial arts, together with the known superiority of crystalline carbons over all other substances, acted as a constant stimulus to continued exertion for the solution of the problem. In the year mentioned, having become associated with an electric light company, at Monongahela, Pa., I found myself in position to conduct experiments on a line which I had some years earlier formulated. The scheme was to cause carbon to be dissolved in melted silicate of alumina, or in the metals reduced therefrom, and by cooling the same to the point of solidification, cause the contained carbon to crystallize. You have heard that "fools rush in where angels fear to tread," and had I been a chemist, it is probable that such an experiment would not have been thought worthy of consideration, and certainly would not have been attempted. Be this as it may, the experiments were made with results more or less satisfactory.

The first experiment was with a furnace constructed of an iron bowl lined with carbon, in the central cavity of which was placed a mixture of carbon and clay; through the mixture was passed an electric current of sufficient amount to fuse the mass—a violent reaction following the fusion—the iron bowl, and a rod of carbon suspended in the centre of the mixture, forming the electrodes. After the mass had cooled, it was removed, broken and carefully examined, when a few bright crystals, blue in color and apparently very hard, were found to be in that part which immediately

surrounded the carbon electrodes. They were exceedingly small and only served to convince me that more and better arranged experiments would produce the desired results.

The iron bowl furnace was replaced with one constructed of refractory bricks, its interior dimensions being 10 inches in length by 4 inches wide and 4 inches deep. Into each end extended a carbon rod, so arranged as to be movable in the direction of its length, thus allowing of a variation of the distance through which the current would have to traverse the charging mixture. The electrical apparatus was arranged for supplying and regulating a current of from 100 to 200 ampères, and of an adjustable potential of from one to fifty volts. The current used was an alternating one, and the action and effects produced were thereby reduced to one of temperature, the probability of electrolytic effects not existing.

The first experiments were confined, more or less closely, to the original lines, as defined by the theory with which I commenced—carbon and clay forming the basis of operation. It was soon discovered that the crystals were not what I had expected to obtain—they were not pure carbon; in color they were usually blue, and their hardness was found to be sufficiently great to abrade the diamond. They seemed, however, to be exceedingly brittle, and it was only in the form of a very fine powder that they were capable of performing this work. Repeated attempts to charge the surface of a copper, or other metallic disc, were productive of failures, as compared with the results obtained with crushed diamond under similar conditions; the crystals being too brittle to withstand the pressure necessary to embed them, or in case of their being embedded, they would be broken and crushed when subjected to use in the manner of the well-known diamond saw.

At this point in the work the want of a name for the new product was felt. It had not been analyzed, and I was led to believe, from the materials used, together with the color, sapphire blue and ruby-red, hardness and general form, that the material was composed of carbon and alumina, and in this belief it was decided to construct the name of the new

material out of carbon and corundum, and it was named carborundum. The fitness of the name, in the eyes of the chemist, is, in view of the now known composition of the substance, doubtful, while in commerce, although phonetic and of pleasing effect in print, it is, perhaps, a trifle lengthy.

I had not continued my experiments long, before certain conditions and results obtained, led me to think the silica present in the furnace played a very prominent part in determining the quality and quantity of the carborundum; and with a view of determining whether or not this was the case, a mixture was made composed of carbon, silica and chloride of sodium; my former experiments having proven the presence of common salt to be beneficial, facili-

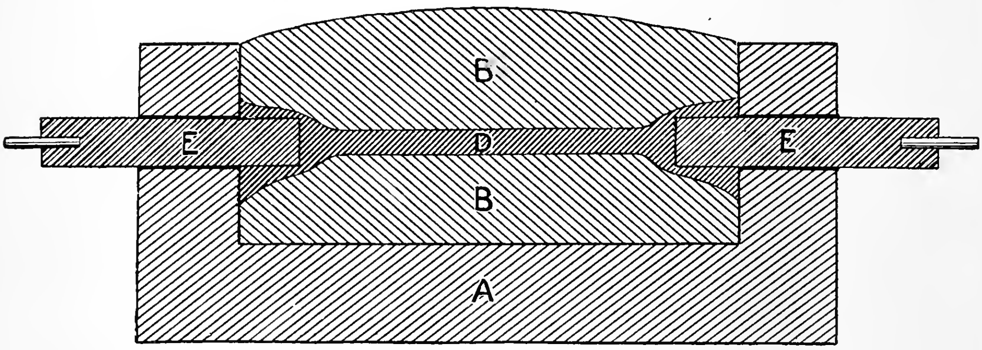


FIG. 1.—Longitudinal section of furnace.

tating the fusion, and to some extent protecting the mass in the furnace from oxidation by air contact. The carbon used was obtained from the carbon rods used in arc lamps, they having been reduced to a powder. These carbons had been made from the coke residue obtained in the distillation of petroleum. The silica was of a good grade of glass sand, its composition not being known. The salt was a good average quality. These materials were mixed in the proportion of forty per cent. each, of carbon and sand, and twenty per cent. of salt, and the mixture was placed in the furnace.

I had met with considerable trouble in operating the furnace from the difficulty in starting the fusion of the mixture, and the continual changes that occurred in the

internal resistance; the contacts, or connection between the electrodes and mixture, were also very difficult to maintain. To obviate or reduce these objectionable features, the connections and chargings were made in the manner shown in the diagram, where *A* represents the walls of the furnace, *B B* the mixture of carbon, salt and sand, *E E* the carbon rods or electrodes, and *D* a core of granular carbon, this core being enlarged at its extremities and made to surround the ends of the electrodes.

The furnace having been prepared in this manner, the electric current was made to pass. The value of this current was never constant, thus: on starting it would have a value of about forty ampères, with a potential of about fifty volts; the ampères would immediately increase, the potential being kept constant until the limit of the apparatus, or 200 ampères, had been reached, at which point the regulation of the potential would begin, finally stopping at about twenty-five volts, the ampères remaining at 200. These changes were produced, on the part of the current quantity, by a reduction in the resistance of the furnace due to the increasing temperature of the core and mixture, fusing of the salt, and eventually to the formation of a black material, consisting of a mixture of carborundum and free carbon, this material having a high conductivity. The reduction of the potential was produced by the ordinary methods of regulation, and was made to prevent the continued increase of the ampères and consequent burning out of the generating apparatus.

An experiment was made with the mixture, arrangements of charge and current as stated, the time required being about four hours. The mass heated slowly, the first outward indication of the internal heat and reactions being the appearance of monoxide of carbon, which was lighted and continued to burn during the remainder of the experiment; later, occasional bursts of white vapors of chloride of sodium would occur, and these would be followed by a flow of melted chloride of sodium, forming miniature volcanic craters.

The action was continued until there was a cessation of

these disturbances, until the blue flames of burning monoxide of carbon became tinged with a deep yellow from the sodium, and until the reduction of the potential indicated a low resistance, resulting from the formation of the black substance above referred to; the current was then stopped, and the furnace permitted to cool and opened.

A representation of the cross-section of the furnace when opened is shown in *Fig. 2*, where *A* represents the walls of the furnace; *B*, the mixture of carbon, sand and salt, now a solid cemented mass consisting of sand and carbon held together with the fused salt; *D*, the carbon core, and *G C* and *W*, zones of portions of the original mixture *B*, now transformed into materials of variable composition.

The results obtained from the first experiments with a

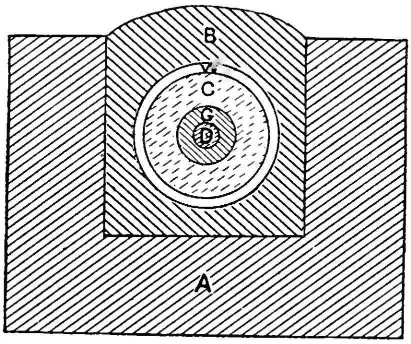


Fig. 2.—Cross-section of furnace.

mixture containing silica, instead of silicate of alumina, were so much superior to the results formerly secured, that the use of clay was abandoned.

Such is a brief sketch of the first manufacture of carborundum. Its further development and present manufacture form a large portion of the history of the Carborundum Company.

The results obtained were so promising that it was thought a lucrative business could be made of the manufacture and marketing of carborundum, and acting on this belief, a company was organized for these purposes. The processes of manufacturing carborundum and the working of it up into marketable form, were elaborated, and up to the present time are undergoing changes and improvements.

One of the first acts of the company was the equipment of a chemical laboratory, and the engagement of Dr. Otto Mulhaeuser, who entered at once into an exhaustive analytical study of carborundum. The results of his labors might be briefly stated as follows:

A sample of carborundum, as originally made from carbon, clay and salt, and having, to the unassisted eye, a blue-black color, but under the miscroscope exhibiting a few crystals of a yellow-green color, some black, some white, with the majority blue, had the following composition:

Si,	60·51
C,	30·09
Al_2O_3,	4·78
CaO,	·17
MgO,	·18
O,	4·27
	100·00

A sample of carborundum, made from carbon, sand and salt, having a clear light-green color, gave as its composition:

Si,	69·19
C,	29·71
Al_2O_3 and Fe_2O_3,	·39
CaO,	·19
MgO,	·06
O,	·47
	100·00

From these figures we learn that what we have called carborundum is, in a pure state, carbide of silicon, responding to the formula SiC, the other substances being impurities. The carbon used in the manufacture of the last sample—the one from sand—was obtained from the coke of bituminous coal, and by it the iron was introduced which we find in the analysis.

The great difficulty met with in obtaining a complete combustion of the carbon, necessitated the reduction of the sample to the finest powder; the samples used for analysis being obtained by floating in water for some minutes, thus

permitting the coarser particles to fall down and be separated from the finer. This latter portion, remaining in suspension in the water, was decanted into another vessel and permitted to settle for some longer period. The degree of fineness of the powder is then indicated by the number of minutes it stood in the first vessel. The necessity for this minute subdivision is shown by the following percentages of carbon as determined from powders of different degrees of fineness, all of them forming part of one original sample:

	Per Cent. C.
Crushed crystals,	24·82
One minute,	25·08
Two minutes,	27·06
Three minutes,	28·04
Four minutes,	29·71

The wonderful permanency of carborundum, when exposed to a high temperature, is also shown by the fact that clean and pure powder heated to bright redness in a current of oxygen for a period of one hour lost only ·41 per cent.; this same quality is also shown in the following determination of silica (SiO_2) formed by the ignition of carborundum (SiC) crystals in the open air in a platinum crucible at a bright red heat for ten hours:

	Grs.
Weight of crucible,	28·5315
Weight of crucible and SiC,	29·0362
Weight of crucible and SiC after ignition,	29·0220
Loss,	·0142
Weight after ignition,	29·0220
Weight after treating with HF and H_2SO_4,	29·0082
SiO_2,	·0138
Total loss,	·0276
Weight of SiC at first,	·5047
	Per Cent.
Total loss,	5·5
Loss per hour,	·55

While the effort is always made to produce carborundum as nearly pure as possible, the conditions of its manufacture are such as to cause a larger or smaller percentage of

impurities to be present. It is, of course, impossible to use a mixture of carbon and silicon as represented in the composition of carborundum, an excess of carbon must be present at the beginning of the process to take up the oxygen present and that entering from the air. It has been found that a very good proportion for the mixture is twenty parts carbon, twenty-five parts sand and ten parts salt (by weight). A sample of carborundum made from this mixture was tested for silica (SiO_2) and a treatment for eight days with hydrofluoric acid (HF) showed the amount present to be 1·56 per cent.

Before entering upon a consideration of the commercial features of carborundum, I will present the following condensed report of the investigations of Dr. Mulhaeuser, as prepared by him at my request for this paper.

The structure and chemical composition of the mass after the reaction was found to be as follows, reference being made to the diagram, *Fig. 2*.

D represents the path of the current, the core of carbon connecting the terminals forming with the latter the resistance by which the electrical energy is transformed into heat energy. This core shows—after the reaction—no change.

G represents a shell of a brilliant black mass which surrounds the carbon core; it consists of crystalline-like aggregates, which are arranged radially to the axis of the core. The part near the core consists of pure carbon, those parts more distant from the axis of the core are more or less mixed with carborundum crystals. A sample of that part gave, for instance, the following analytical results:

	Per Cent.
Free carbon,	66·29
Carborundum,	33·71

The free carbon has all the properties of graphite, it blackens the fingers, etc. The carborundum found in this zone *G* gave the following numbers:

	Per Cent.
C,	30·49
Si,	68·26
Fe_2O_3,	0·77
CaO,	0·48

To separate the carbon from the carborundum the mass is heated with hot oxygen. The crystals obtained in this way, though they possess generally the properties of carborundum, seem to differ a little in their optical qualities. They show, after having been freed from carbon, all the colors of the spectrum; especially brilliant are the red and violet rays.

C represents the chief product of the reaction, the zone of the carborundum, chemically spoken of as crystallized carbide of silicon. The zone of carborundum surrounds the graphite zone. The crystals are arranged radially to the axis of the core, and form in general a bright green shell. For the purpose of analysis, a sample of that shell was reduced to a powder of the proper fineness and gave the following figures:

	Per Cent.
Si,	62·70
Fe_2O_3 and Al_2O_3,	0·93
MgO,	0·11
C,	36·26

This analysis showed clearly that carborundum consists essentially of carbon and silicon associated together in the proportion of one atom each. In order to clean the product, to free it from iron, aluminum, etc., the powder was treated in the following manner: First with hydrochloric acid, then with dilute caustic soda and water, then the powder was put in a combustion tube, heated to dark redness and a current of oxygen passed over it for about one hour. All free carbon and perhaps a little of the combined carbon is burned off and a powder obtained, which contains now only silica, acid, traces of magnesia, alumina and iron, besides the carbide of silicon. By treating the powder with hydrofluoric acid, the carbide of silicon is obtained nearly pure. One of the many samples cleaned in this way, gave the following results:

	Per Cent.
Si,	69·10
C,	30·20
Al_2O_3 and Fe_2O_3.	0·49
CaO,	0·15

A compound having the formula SiC contains seventy per cent. Si and thirty per cent. C.

If pure carbon and pure silicic acid be taken the carborundum crystals will be white; if these materials contain iron, the crystals show a greenish-yellow color.

The crystals are not dissolved either by hydrofluoric acid or by any other acid; they are slightly attacked by dilute caustic and carbonated alkalies; and they are decomposed by caustic or carbonate of soda by fusion. The carbon is separated and silicon is transformed in silicic acid, the whole mass becomes black, then after some time the carbon burns off.

When reduced to a very fine powder and floated in water, carborundum does not settle, even after a period of months, It behaves like a colloidal substance, for instance metallic silver. By adding an acid or a salt, the extremely fine powder settles.

W represents a white or gray-greenish looking shell, surrounding the zone of carborundum crystals. The mass consists of small pieces of the size of the original sand grains. These pieces are soft and may be reduced very easily to a fine powder. The qualitative analysis showed that the powder had the same constituents as the carborundum crystals, and the powder was, therefore, cleaned in the same manner as in the case of those crystals. The white-green shell was crushed and alternately heated with hydrochloric acid, caustic soda, water, hot oxygen and hydrofluoric acid. The resulting powder had the following composition:

	Per Cent.
C,	27·93
Si,	65·42
Fe_2O_3 and Al_2O_3,	5·09
CaO,	0·33
MgO,	0·21

We may say then, that the powder consists essentially of carbide of silicon. But this carbide of silicon is different from the other one in that it forms no crystals, is amorphous and very soft, and of no value as an abrasive. It has been obtained at a comparatively low temperature—far distant from the core—and is identical with the product recently obtained by I. Schützenberger.

[*To be continued.*]

A NEW METHOD OF SEPARATING THE WHITE, FROM THE RED, BLOOD CORPUSCLES, BY MEANS OF THE HÆMATOKRIT.

BY JUDSON DALAND, M.D.

Instructor in Clinical Medicine and Lecturer on Physical Diagnosis and Symptomatology in the University of Pennsylvania; Assistant Physician to the University Hospital; Physician to the Philadelphia Hospital and to the Rush Hospital for Consumptives.

[*A lecture delivered before the Franklin Institute, December 9, 1892.*]

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Before referring to the methods of separating the white from the red blood corpuscles, it may be of interest if I mention briefly a few of the more important facts regarding the blood.

This fluid has been the object of study by all physicians at all places, at all time; and this interest has not been confined to physicians, but has exercised its fascination over the remaining professions as well as the general public.

All through literature, both scientific and secular, constant reference is made to this wonderful liquid.

Notwithstanding the centuries that have been devoted to research in this direction but little was known of the exact composition of the blood in health and disease until the early part of the present century, and our knowledge of the existence of the red blood cells is but 220 years old.

The blood may be described as having a bright scarlet-red color in arteries, and dark bluish-red when obtained from a vein; its reaction is neutral alkaline; its odor peculiar but difficult to describe; its taste is saline; its specific gravity averages 1·055 and its temperature varies from 99° to 100° F.

SHOWING THE VOLUME AND NUMBER OF RED AND WHITE CORPUSCLES.*

Number of Case	Age.	Sex.	Volume of White Corpuscles.	Volume of Red Corpuscles.	Number of Revolutions.	Hæmaglobin Fleischl Test	Number of White Corpuscles.	Number of Red Corpuscles.	Probable Number of Red Corpuscles as Estimated from the Volume.	Diagnosis and Remarks.
						per cent.				
1	27	F.	1	42	10,000	5·4 or 38	6,783	3,220,000	4,200,000	Diabetes with typhoid fever.
2	34	M.	1	30	10,000	7·4 or 53	10,150	3,150,000	3,000,000	Hepatic cirrhosis. Internal jaundice Blood looked red and watery.
3	20	M.	1	40	10,000	11·2 or 80	6,433	5,950,000	4,000,000	Acute croupous pneumonia. Third stage.
4	20	M.	1	44	10,000		7,155	5,775,000	4,400,000	Same case two days later.
5	21	M.	2	54	20,000	11·9 or 85	10,803	5,975,000	5,400,000	Acute croupous pneumonia. Second stage.
6	21	M.	2	48	20,000	—	13,630	5,463,000	4,800,000	Same case two days later.
7	33	F.	1	12	10,000	—	6,210	1,450,000	1,200,000	Gastric carcinoma. Intense anæmia. Blood looked pink.
8	65	M.	½	12	10,000	1·4 or 10	3,203	600,260	1,200,000	Essential anæmia. Blood pink and watery, and bled freely from puncture.
9	65	M.	½	8	10,000	10	3,900	562,500	800,000	*Ibid.* Diagnosis confirmed by autopsy.
10	43	M.	4	40	20,000	—	28,523	4,962,500	4,000,000	Acute croupous pneumonia. Second stage.
11	43	M.	1	44	10,000	80	9,050	5,437,500	4,400,000	*Ibid* Convalescent and afebrile.
12	17	M.	2	32	10,000	—	15,414	5,375,000	3,200,000	Acute rheumatic pericarditis.
13	17	M.	2	36	10,000	—	18,471	4,720,000	3,600,000	*Ibid.*
14	17	M.	2	36	10,000	7·7 or 55	18,662	4,412,000	3,600,000	*Ibid.*
15	19	F.	1	30	10,000	7·7 or 55	8,340	4,180,000	3,020,000	Chronic endocarditis. Acute pleurisy. Temperature 38° C.
16	58	M.	1	28	10,000	—	8,057	3,181,808	2,800,000	Gastric carcinoma.
17	46	M.	1	24	10,000	—	7,070	3,593,750	2,400,000	Chronic peritonitis with ascites.
18	33	M.	1	20	10,000	—	12,102	2,230,000	2,000,000	Intestinal hemorrhage.
19	28	F.	3	50	20,000	—	24,000	5,250,000	5,000,000	Fourth day of acute croupous pneumonia of right lower lobe.
20	28	F.	3	48	10,000	—	22,484	5,787,500	4,800,000	*Ibid.* Eleventh day of the disease. No fever.
21	70	F.	2	18	10,000	35	32,000	2,712,500	1,800,000	Chronic interstitial nephritis confirmed by autopsy.
22	46	M.	4	28	20,000	45	32,248	3,637,500	2,800,000	Malignant sarcomatosis confirmed by autopsy.
23	15	M	1	17	20,000	30	1,719	2,062,800	1,700,000	Lymphatic and splenic pseudo-leukæmia.
24	15	M.	½	16½	10,000	—	2,102	2,160,000	1,650,000	*Ibid.*
25	15	M.	½	16	10,000	30	4,012	2,187,500	1,600,000	*Ibid*
26	21	F.	1	42	10,000 s	—	11,783	5,962,500	4,200,000	Acute Bright's disease.
27	38	F.	1	33	10,000 s	—	9,936	4,410,000	3,300,000	Pregnancy.
28	45	M.	1	36	10,000 s	55	3,503	4,956,000	3,600,000	Tertian intermittent fever.
29	36	F.	2	36	10,000 s	—	17,006	5,237,000	3,600,000	Acute myelitis.
30	29	F.	13	20	20,000 s	40	330,956	3,025,000	2,000,000	Splenic leukæmia.
31	29	F.	13	24	20,000 s	40	275,000	2,900,000	2,400,000	*Ibid.*
32	29	F.	13	25	20,000 s	40	181,250	3,160,000	2,500,000	*Ibid.*
33	29	F.	13	22	20,000 s	—	180,000	3,575,000	2,200,000	*Ibid.*
34	29	F.	1	33	10,000 s	—	6,496	3,470,969	3,300,000	Tumor cerebri syphilitic.
35	20	M.	2	36	20,000 s	65	16,123	4,830,000	3,600,000	Acute articular rheumatism.
36	20	M.	2	42	20,000 s	—	7,126	4,840,000	4,200,000	*Ibid* Articular rheumatism.
37	33	M.	2	48	20,000 s	12·6 or 90	13,695	5,864,000	4,800,000	Perityphlitis, afebrile.
38	21	M.	1	50	10,000	—	—	5,037,500	5,000,000	Chlorosis.
39	21	M.	1	52	10,000	55	—	5,387,500	5,200,000	*Ibid.*
40	67	M.	1	30	10,000 s	65	7,197	3,974,500	3,000,000	
41	23	F.	1	27	10,000	35	6,170	3,200,000	2,700,000	Chronic parenchymatous nephritis.
42	27	F	1	38	10,000	—	4,108	4,637,500	3,800,000	Simple anæmia.
43	24	M.	1	38	10,000	—	—	3,937,000	3,800,000	Simple anæmia.
44	40	M.	2	70	10,000	102	12,172	6,912,000	7,000,000	Cholera nostra.

* The counts here given made by my colleague, Dr. Carl Seiler, are marked "s."

The total quantity of blood is estimated as one-thirteenth of the body weight, *i. e.*, a man weighing 130 pounds contains ten pints of blood.

Broadly speaking, the blood is composed of a fluid called *plasma*, in which float small solid bodies, known as the *red* and *white* blood corpuscles.

The plasma is a liquid composed of salts and albumin dissolved in water. The red blood cell is a round body four times as broad as it is thick, concave on each side, with rounded edges and measures about $\frac{1}{3000}$ to $\frac{1}{3500}$ of an inch in diameter, and with a tendency to form rouleaux.

When viewed under the microscope it is light yellow in color, which color is due to the presence of blood pigment or hæmaglobin.

The white blood corpuscle is a spherical body, the average size of which is a trifle larger than a red blood corpuscle; it is colorless and is possessed of the curious property of throwing out processes and retracting them, which is called amæboid movement.

Some years ago an attempt was made to count the number of red and white corpuscles in each cubic millimetre of blood, and finally the Thoma-Zeiss blood counter was constructed. The instrument is composed of a capillary tube which opens into an olive-shaped bulb, containing a small glass ball about the size of a large shot. The second portion consists of a glass slide, in the centre of which is an elevated disc surrounded by a gutter. When a glass cover is placed on top a shallow cell is formed, having known dimensions. On the surface of the disc is traced a series of lines, bisecting each other in such a way as to form sixteen small squares.

By aid of the graduated pipette the blood is diluted with a two and one-half per cent. solution of potassium bichromate in the proportion of $\frac{1}{100}$. This is thoroughly mixed in the bulb of the pipette, with the aid of the glass ball, by thorough shaking. A drop of this diluted blood is then placed upon the slide, over which is placed a cover glass. The number of red cells in each small square are then counted. This number is multiplied by the dilution, and

this result again by 4,000, because each square is but the $\frac{1}{4000}$ of a cubic millimetre, and finally this result is divided by the number of small squares counted.

The process proved so uncertain in its results, and requires so much time and patience, that, in 1885, Professor Blix first suggested the use of centrifugal force, and later Dr. Hedin perfected this instrument, which I herewith demonstrate.

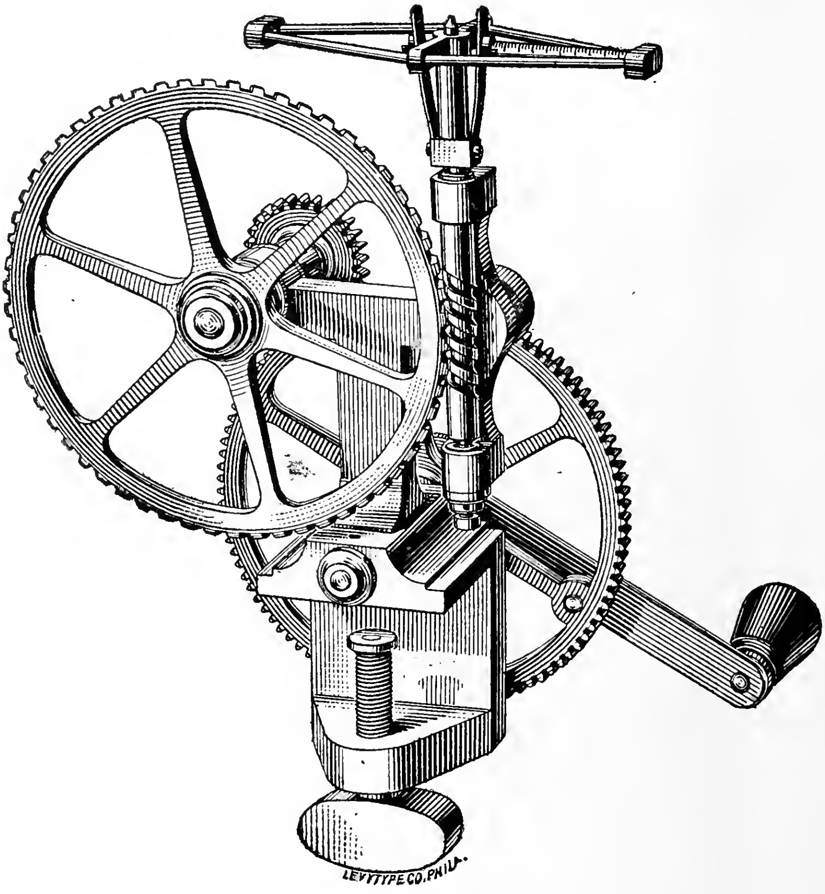


FIG. 1.—Hedin's hæmatokrit.

It is so constructed that one revolution of the large wheel, to which is attached the handle, causes the brass frame at the top of an upright piece of steel to revolve 104 times. This frame is so arranged that it receives two glass tubes, which are to contain the blood, each measuring thirty-five millimetres long, and held securely in position by a spring. The apparatus is extremely simple, compact, durable, and is admirably adapted for the purpose for

which it is intended. The glass tubes, that are to contain the blood to be rotated, have a capacity of 27·489875 cubic millimetres, are 3·75 millimetres thick, 35 millimetres long, and have a calibre throughout measuring one millimetre in diameter. On the outside is a scale dividing it into fifty equal parts, in the same manner as the scale on an ordinary thermometer. The method of determining the

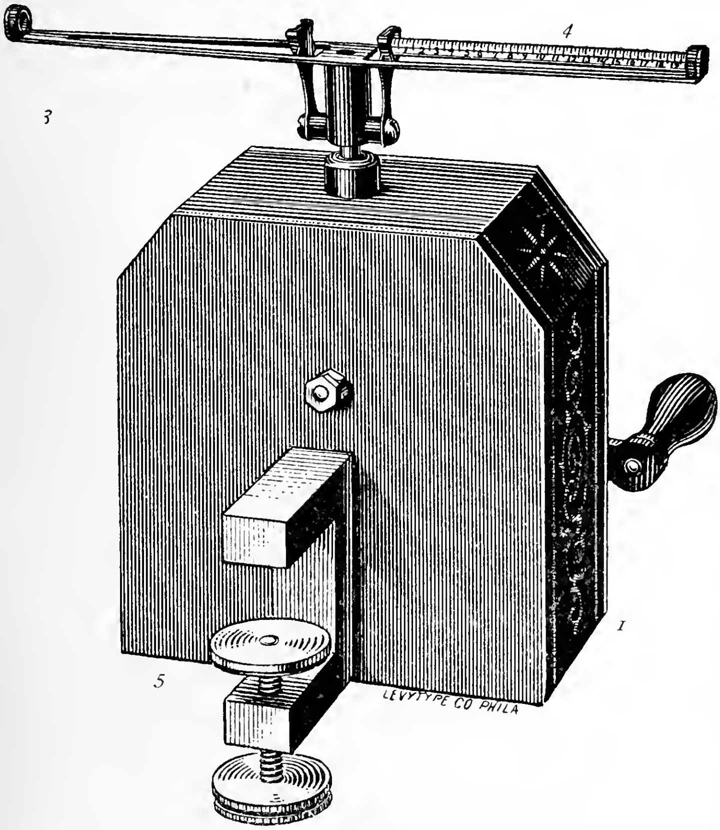


FIG. 2.—Author's hæmatokrit.

1, Box containing mechanism for rotating.
2, Handle of crank.
3, Frame which rotates 10,000 times per minute.
4, Improved capillary tube to contain the blood with scale.
5, Clamp to fasten apparatus to a table.

volume of corpuscles is very simple: the blood is mixed with an equal quantity of a fluid preventing coagulation, and is then rotated; the red corpuscles form a column at the periphery of the tube, and measure, we will say, twelve and one-half. As the blood is diluted one-half, this result is multiplied by 2 = 25, and to convert this into percentage

it is again multiplied by 2, as the scale is divided into but fifty parts, which gives fifty per cent.

The improved hæmatokrit (see *Figs. 2* and *3*), which I have suggested, and which I exhibit this evening, presents the following advantages:

The tubes (see *Fig. 5*) measure seventy millimetres in length, the lumen is *reduced* to one-half millimetre in diameter, and the divisions on the scale *increased* to 200, so that the percentage is at *once* determined. Under these conditions, the divisions on the scale indicate the volumetric

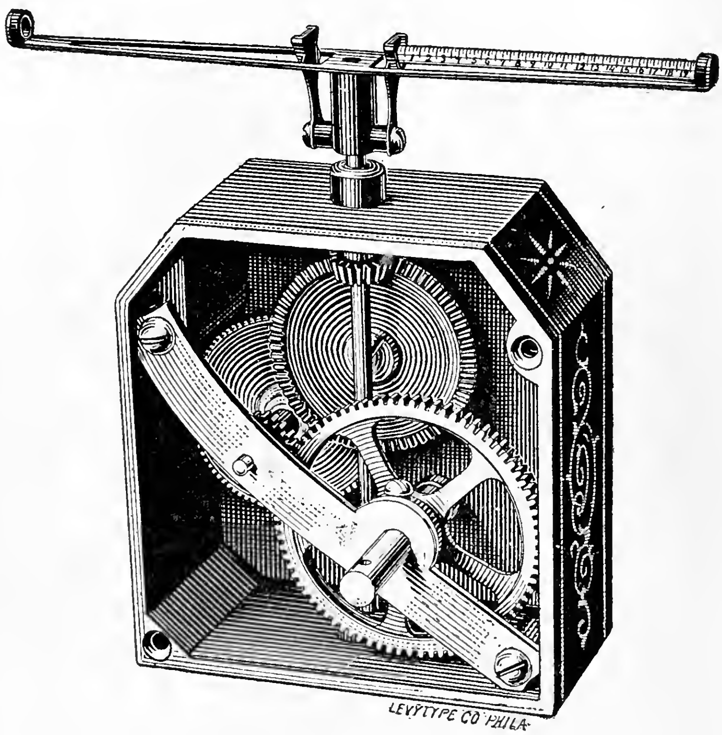


FIG. 3.—Interior view of author's hæmatokrit.

percentage. The longer column of blood will not only secure greater accuracy in reading the results, but also enables one to determine, with almost equal certainty, the volume of white corpuscles which, owing to their relatively lower specific gravity, form a second white column on the inner side of the red corpuscles.

The selection of a diluting liquid required much thought, time and labor. It becomes at once evident that this fluid should possess the following properties:

(1) It should absolutely prevent coagulation.

(2) It should preserve the normal shape of the corpuscles.

(3) It should harden the corpuscles so that no rupture occurs while rotating.

(4) It should give a *constant* volume in the *shortest* time.

(5) It should give the *largest* volume, so insuring greater accuracy in reading the result.

(6) It should possess a contrast color to that of the glass pipette, so facilitating and rendering more accurate the measuring of the diluting liquid.

(7) It should have no deleterious effects upon the white corpuscles.

(8) It should be of simple composition and form a permanent solution.

In experimenting with different liquids, blood from the same individual was taken, usually at the same hour, between 10 A.M. and noon, and afterward the blood that had been rotated was examined microscopically.

In determining the time required to obtain a fixed volume, observations were made every thirty seconds for ten minutes.

After a series of experiments lasting nine days, during which time nineteen different solutions were examined, I proved that a two and one half per cent. solution of bichromate of potassium fulfilled these conditions.

The solution possesses all the attributes of an ideal diluting fluid, namely:

(*a*) Absolutely preventing coagulation.

(*b*) Preserving the normal shape of the corpuscles.

(*c*) Hardening and so preventing rupture of the corpuscles.

(*d*) Giving a constant volume in sixty-six to seventy seconds.

(*e*) Giving the largest volume, thus diminishing the error in reading from the scale.

(*f*) Possessing a dark yellow color, contrasting strongly with that of the glass pipette, thus enabling one to measure the liquid with accuracy and ease.

(*g*) Staining the red cells so that the division between the column of red and white corpuscles is plainly seen.

(*h*) Apparently hardening the leucocytes.

(*i*) Making an extremely simple and stable solution, only requiring to be well corked to protect it from evaporation.

Lastly, an experience of four months, not only of myself, but also of my colleagues in the laboratory, *proves it to be by far the most useful liquid to dilute the blood for counting red blood corpuscles.*

A careful study was then made to determine the minimum amount of time required to secure a constant volume of red blood corpuscles, and after thirty observations it was shown that 100 revolutions of the larger wheel, or 10,000 revolutions of the frame carrying the tubes containing the blood, were amply sufficient when the 2·5 per cent. solution of potassium bichromate was employed. When the larger wheel was rotated 100 times rapidly, it required sixty-six to seventy seconds. Further rotation for one, two or more minutes was rarely successful in producing a reduction of one-fourth of a volume. In cases of extreme *leucocytosis* 200 rotations were found necessary, probably due to the relatively very light specific gravity of the white corpuscles.

In making a volumetric examination of the blood, the following articles are necessary:

(1) Alcohol.

(2) Ether.

(3) Large pin or a small lancet.

(4) Capillary pipette drawn to a point with a rubber tube.

(5) 2·5 per cent. solution of bichromate of potassium.

(6) Small watch-glass.

(7) Rubber tube to be attached to the glass tube of the hæmatokrit.

The lancet is first cleaned and then disinfected by the use of alcohol. The thumb of the left hand is most convenient. It should be thoroughly washed with ether and then allowed to dry, care being taken that no filaments from the towel remain. After making the incision, gentle pressure, causing the wound to gap, was usually found sufficient to produce a drop of blood the size of a pea; this was drawn into the pipette by suction, and an equal quantity of the bichromate solution added and thoroughly mixed in a

watch-glass. The hæmatokrit tube was then *immediately* filled by suction, one finger being held over the free end to prevent the displacement of blood, which would otherwise occur upon removal of the rubber tube. The filled tube is then placed in the frame of the hæmatokrit, and also a second prepared exactly in the same manner. The larger wheel is then rapidly rotated 100 times, and the results read from the scale, multiplied by 4, give the pecentage volume. The whole procedure should be done as *quickly* as possible, and particular care should be taken, as soon as the blood is mixed, that it be immediately rotated, otherwise the results obtained will indicate a larger volume of blood than really exists. The increased volume noticed upon allowing the mixed blood to remain in the watch-glass for a few minutes is probably due to the settling of the red blood corpuscles to the bottom because of their comparatively high specific gravity, and also to evaporation.

Having determined upon the method of pursuing the examination of blood by the hæmatokrit, it became important to determine the normal volume and its variations. For this purpose *thirty* healthy medical students, with an average age of twenty-four, were examined, and the percentage volume varied from sixty-two to forty-four, averaging fifty-one per cent.; a similar observation upon eight female nurses showed a variation of from forty-two to thirty-six, averaging forty-four per cent., or seven per cent. less than in the males. As the blood-counting apparatus is considered the best method of determining the number of red and white blood corpuscles, an attempt was made to show their relative accuracy, and also the probable number of corpuscles for each percentage volume. To accomplish this the blood from twenty-five healthy men, physicians and students, was examined for the percentage volume, and at the same time a count was made with the following result: The average age was twenty-six years; the maximum volume observed was sixty-six per cent., and the minimum forty-four per cent., and an average of all the cases examined gave 51·8 per cent. volume. The red blood corpuscles in each case were carefully counted, and for this purpose the Thoma-

Zeiss hæmacytometer was employed. The average of all the counts made gives 5,088,442, and this being the case, one per cent. of volume is the equivalent of 98,578 red blood corpuscles. The difference between 99,390 and 100,000 is but 610; and, as in disease the average volume is reduced to 33·5, the greatest possible difference is but 20,435, a number so small as to be safely considered of no practical importance. In my opinion, therefore, for convenience, *one percentage volume may be considered as representing 100,000 red corpuscles.* This number greatly facilitates the calculating of the number of corpuscles present. When the percentage volume has been obtained, all that is necessary is to add five ciphers, and the number of corpuscles are indicated.

It is extremely interesting and important to note that the average volume of the thirty cases examined gave 51·5 per cent., and that this series of twenty-five gave 51·8 per cent., a difference of ·3 per cent., or 29,361 red blood corpuscles. These two series of observations, numbering in all fifty-five cases, prove most conclusively, first, that the average physiological volume for young men about twenty-six years of age is 51·6 per cent., and further, the fact that the average volume in both series speaks well for the *accuracy* of this method. With reasonable care the error by this method should fall within four volumes, or, roughly speaking, should not exceed 400,000; and when the modified apparatus here shown is adopted, it is quite certain that this working error may be reduced fifty per cent. or more, so that one may confidently expect that the volumetric reading shall fall within 200,000 of the true number of corpuscles, a deviation from normal so slight as to be of no practical importance.

From my own personal experience, and that gathered from my colleagues regarding the results obtained by the use of the Thoma-Zeiss hæmacytometer, a difference of two-, three-, five-hundred thousand, or more, is not at all unusual.

Reinert has clearly shown that this instrument gives a *theoretic* error of three per cent., or 150,000, in the hands of experts, and in *practical* clinical work, as will be proved later, it is certain that this error is considerably increased.

In making these observations, an effort was made to determine the normal volume of white corpuscles, but the extremely narrow white band, scarcely a line in width, renders accurate observations extremely difficult and often impossible. It was noticed, however, that in health the column of white corpuscles was never wider than one of the division lines cut in the glass tube. Any *considerable* increase in the white corpuscles is at once detected. The glass tube is modified, as here shown (see *Figs. 4* and *5*), so that the diameter of the lumen is decreased and the length doubled, permits of a more satisfactory study of the white corpuscles.

An analysis of the series of twenty-five cases referred to shows that the average age was twenty-six years; that the maximum volume observed was sixty-six per cent., and the

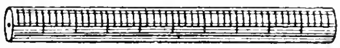


FIG. 4.—Original capillary tube, exact size.

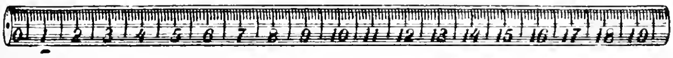


FIG. 5.—Author's modified tube, showing its *exact* size and precise appearance of the scale.

minimum forty-four per cent., and an average of all the cases examined gave 51·8 per cent. volume. The red blood corpuscles in each case were carefully counted, and for this purpose the Thoma-Zeiss hæmacytometer was employed. The average of all the counts made gives 5,088,442, and this being the case, one per cent. of volume is the equivalent of 98,578 red blood corpuscles.

With this improved hæmatokrit one may make an examination in from five to ten minutes and determine at a *glance* the *volume* and *number* of *red* and *white* corpuscles.

In many of my cases the volume and number of corpuscles do not agree when five ciphers are added to the percentage volume, and this may be explained:

(1) By the variable results obtained, especially when we make but one preparation, and count sixty-four squares, as was done in the majority of the cases reported, and

(2) That the blood used to determine the volume was always mixed with the bichromate of potassium solution in the ampulla of the Zeiss pipette, and not separately measured and mixed in a watch-glass; and therefore, in all cases where the tendency to coagulation was increased, the volume was eight or more per cent. less than really existed.

From the studies which I have here recorded, the following opinion is deduced *that the hæmatokrit gives as accurate, if not more accurate, results than the Thoma-Zeiss apparatus as ordinarily employed, requires less skill, calls for no eye-strain, and the volume of red blood corpuscles, and number per cubic millimetre, and volume of white corpuscles, may be determined within ten minutes.*

In conclusion, I beg leave to call your attention to a table, showing variation in the volume of the blood cells in a variety of diseases.

A NEW TELE-PHOTO LENS.

BY JULIUS F. SACHSE.

[*Read at the stated meeting of the Institute, held May 17, 1893.*]

MR. PRESIDENT AND MEMBERS OF THE FRANKLIN INSTITUTE, OF PHILADELPHIA:

Towards the close of the year 1891 the scientific world was startled by an announcement made by Dr. Adolph Miethe, of Berlin, before a meeting of the Society of Practical Photographers, in Berlin, that a photographic objective had been constructed upon an entire new principle, which would overcome distance to an extraordinary degree, and with a normal extension of camera length would produce results heretofore thought to be impossible.

At this meeting, held November 4, 1891, a specimen print was shown, the image of a monument on the Rhine taken from the opposite shore at a distance of over 2,000 metres, and measuring ten centimetres.

Almost simultaneously with this announcement came one from the noted English optician, Thomas R. Dallmeyer,

giving notice of a similar invention by which he had obtained, with an ordinary camera, the image of a crow in mid-air over 100 yards distant, measuring about three-fourths of an inch from tip to tip.

The description of the new objective of Dr. Adolph Miethe, together with specimen prints were first brought before the American public by the speaker in the February and March numbers of the *American Journal of Photography*, for 1892. Subsequently the matter was brought to the notice of this Institute by one of your members.

These specimen results, which showed one of the greatest advances made for years in photographic optics, naturally created considerable attention in scientific quarters, and numerous experiments were made to construct similar lenses in this country.

One of the most enthusiastic experimenters in this field of photographic optics was your fellow-member, the late W. A. Cheyney, a man thoroughly versed in the science of optics. Mr. Cheyney's experiments were conducted upon similar lines to the foreign ones, as laid down by Dr. Adolph Miethe, viz: A combination of the regular objective with a negative element fixed in an adjustable draw tube, independent of the adjustment of the camera-bellows. Specimens of results obtained by him showed satisfactory progress; his labors, however, as you know, were interrupted by his untimely death.

Another experimenter, who became interested in the new departure in photographic optics, was Mr. Albert B. Parvin, also of this city, and I now have the honor to introduce to you for your inspection and consideration a result of his labors, viz: A new tele-photo lens, which differs in construction and action from its European prototypes.

In the first place, the new objective is contained within an ordinary lens tube two and five-eighths inches long, and it requires no delicate adjustment prior to taking the camera focus. Secondly, the remarkable rapidity or speed with which the new lens works, in direct contrast to the European systems which are not rapid enough for instantaneous work. A specimen print which I have here to show you, according

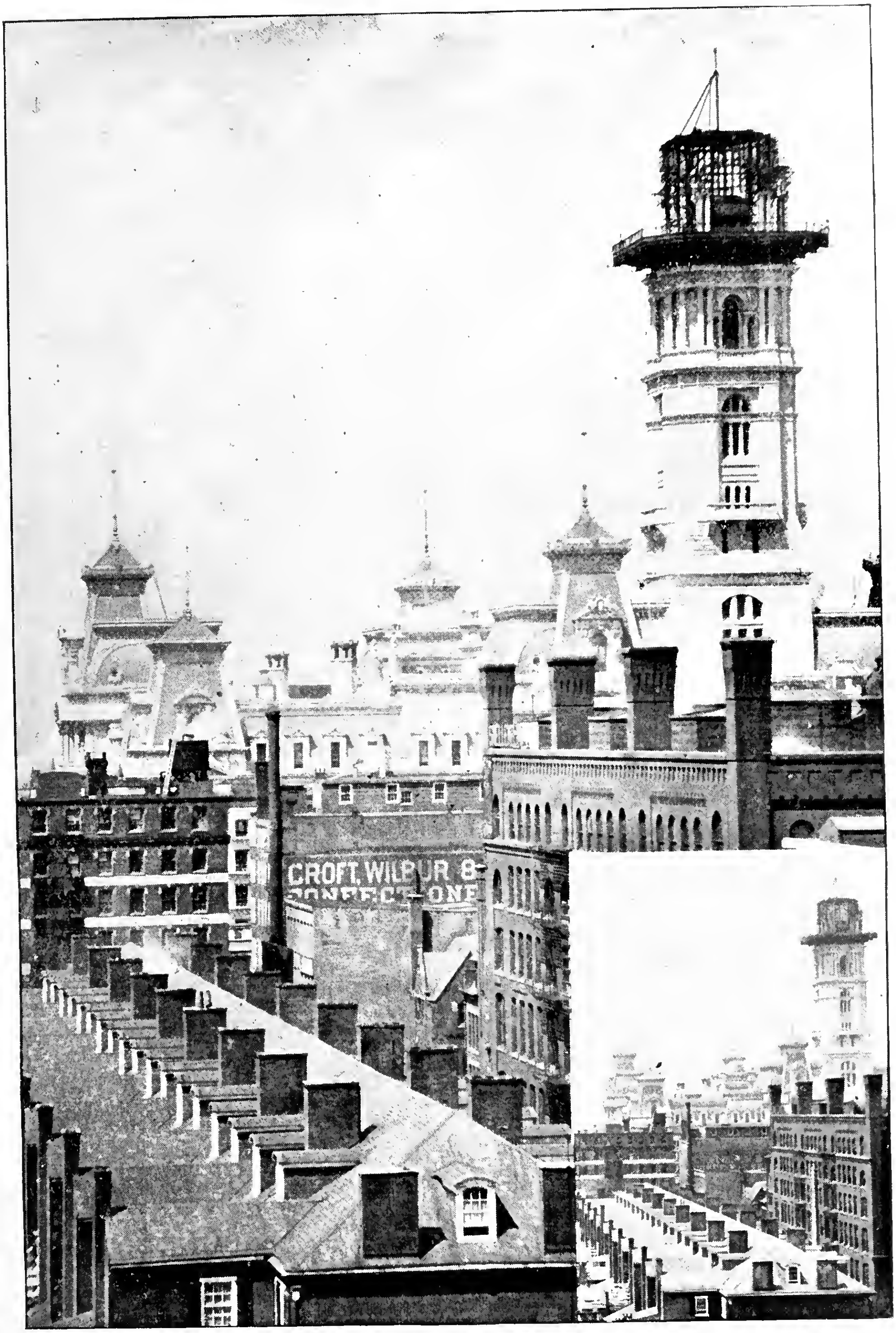
to the maker, was taken on a cloudy day, at half a mile range, stop f/42, in one-fiftieth of a second. The picture certainly shows excellent illumination and sharp definition, even the cordage of the vessel being clearly cut. Another pecularity claimed for this new tele-photo lens is its covering power. The lens here for your inspection is one and three-thirty-seconds of an inch in diameter, equal to what is known as a Ross 6 x 5 lens, yet, as you will perceive by the specimens here shown, it more than covers a 10 x 12 plate sharply, while the same test (*C*), made with a 5 x 8 Beck lens, which is about an inch and a quarter in diameter, falls far short of covering the plate.

As to the "tele-focal" powers of the new lens (if I may use the term), a comparison of the two views, marked *A* and *B*, will give some idea of its scope. Both are taken from the same standpoint, the former (*A*) is taken with the new Parvin lens, the latter (*B*) with a Beck lens of almost the same diameter. These three experiments *A B* were all made by the inventor from the same standpoint. Exposure, *A* two seconds, *B* three seconds, *C* two seconds, stop in all *f*/64.

An examination of the Parvin picture will show the depth of focus and its claim to absolute rectilinearity.

As to my personal experience with the new tele-photo objective, I will state that upon two occasions I had an opportunity to test the new objective, both experiments were, however, confined exclusively to trials in focussing upon the ground glass, the main object being to calculate the magnification, and determine its powers and possibilities in actual practice and its adaptation for scientific work, such as falls to the every-day lot of the naturalists or geologists, by affording means to record photographically objects which are beyond the focal length of the ordinary objective. These comparative tests, made with both 8 x 5 Darlot objectives, showed that the magnification of the new lens was about five times greater than the regular objectives of equal diameter.

Excellent results were shown upon formations distant by actual stepping, from 100 to 1,000 yards, the finest details being sharp and clear-cut with an open aperture, the camera extension being fifteen inches.



Comparative test of the Parvin tele-photo lens and rapid rectilinear lens of equal diameter, both taken from the same standpoint.

In focussing upon distant objects, distant from three to four miles, such as the Fairmount Observatory from Belmont, the iron rods and structure showed plain and distinct against the sky.

The same may be said of the tower of the new City Hall, distant four miles from the same standpoint, which with the old objectives from the same standpoint are hardly discernible. These results led me to believe that tele-photo lenses of this character, *i. e.*, of a system of moderate amplification, would be of considerable value in the hands of the scientific student and photographic tourist. Such lenses, as they become better known, will no doubt prove indispensable to the amateur and tourist, as it will give opportunities for obtaining views and bits of detail otherwise unobtainable with the means which under ordinary circumstances are within the reach of the travelling amateur. Such lenses offer to him magnification in addition to rapid work and sharp definition. For very close work, such as laboratory or studio work, I find that the new lens is not so well adapted as some of the older forms of objectives, the magnification being a fixed one. This, however, is not to be taken as detrimental to the new objective, as the sample furnished for experiment was intended entirely for distant outside work. It is stated, that in the near future, specimens will be forthcoming where the same principle is adapted for interior work.

In conclusion, I will state that no such extreme telescopic properties are claimed for the new Parvin lens as have been shown by the German and English lenses. I allude to such views as that of Mont Blanc, taken from Belleview near Geneva, at a distance of forty-four miles, by Fred Boissonas, which was lately exhibited in this city. Further, this view was made in a camera built expressly for the purpose, with a draw of sixty-six inches, the time of exposure being ten minutes.

The claim made for this Philadelphia tele-photo lens is that it is a simple and practical objective, having a fixed system of magnification, the whole being constructed for ordinary use in the hands of the average photographer of the day.

One of the greatest advantages claimed for the new lens, over all the European telescopic lens system, is the fact that the new lens works instantaneously even when stopped down to f/45. The *Photographische Nachrichten*, published in Berlin no later than April 27th last (p. 216), distinctly mentions that the German tele-photo objectives are not suited for instantaneous work. Here we have proof of the claim of the new American objective. I submit for your inspection a number of comparative photographs, all made by the inventor of the new lens, which will enable you to judge intelligently of the magnification, covering power rectilinearity and speed, some of them being produced by an exposure of one-fiftieth of a second.

I now leave the subject in your hand for further investigation.

The Manufacture of Antique Persian Rugs.

By H. Endemann, Ph.D., Chemist.

Some time ago I found in one of our daily papers an article complaining of the sale of imitation antique rugs for the genuine article. Having come into the possession of one of these, I experimented with it, not only with the view of devising a plan for readily detecting the spurious nature of these goods but, incidentally, regarding the probable method by which they were produced.

Later on I will give a method which is capable of producing as beautiful a specimen of an antique rug from a bright-colored Persian rug as ever delighted the eye of antique hunting buyers. The rugs as found, however, show all more or less traces of their treatment. On close inspection it is easily observed that some of the bright colors of the wool have run into the cotton margin, which is itself discolored throughout and gives reactions for iron as well as tannin compounds, but otherwise the rugs look as if really age only had wrought the changes observable.

The wool is more decolorized on the outside than on the inside, where it is firmly held by the warp, and an inspec-

tion in this direction will therefore not reveal the spurious nature of the goods. For this fact of a more thorough destruction of the color on the surface where atmospheric influences, as moisture, air and light, have acted more thoroughly is true likewise for the real antique article, where we find the color destroyed also more on the surface than on the inside.

Also the softness of the artificially made antique rug compares well with that observable in the genuine goods.

An examination of the colors on the wool is hopeless when we have to deal with colors destroyed and changed to such an extent as I found them in this class of goods. The real test can therefore be best made on the cotton margin by chemical reactions and general inspection.

The preliminary examination taken into account, I set out to unearth the probable mode of manufacture.

It was soon found, that all bleaching agents, while they removed sufficient color in some cases, left the colors rather in bright shades, and alone could therefore not have been used for the production of the antique rug, *i. e.*, the colors must be toned or shaded to produce the desired result.

I shall not go into the details of all possible methods but go at once to the description of the method which I consider to be the most serviceable and therefore very likely the one used in the production of such spurious goods as I had occasion to see. The first step is to discharge most of the color by means of an alkaline bath.

For ten rugs (25 x 40 inches each) dissolve one pound of borax in 120 gallons of water and heat to about 140° F., then prepare a concentrated solution of caustic soda, two and one-half pounds to about two gallons of water.

Then add one-third of this solution to the warm borax solution and enter your rugs, working them constantly by hand or reel, at the temperature mentioned. During one hour while they are worked the rest of the caustic soda is added in small portions, taking the precaution that the newly-added alkali is thoroughly mixed with the old solution before the rugs re-enter.

At the end of this time considerable color will have

passed into the solution, which is then run off and replaced by fresh water repeatedly to remove the alkali.

The rugs are then allowed to dry, when dry they are put for a short time into a solution of extract of fustic, one to 100, and again allowed to dry (one pound extract of fustic to twelve gallons of water). They are now bleached in the following solution: One gallon commercial hydrogen peroxide is mixed with thirty-five gallons of water and thereto is added one-fourth gallon strongest aqua ammonia.

The rugs are entered and remain therein until sufficiently decolorized. The colors now, though quite towards the yellow, are still bright.

The rugs are now taken out, wrung and at once brought into a bath of four fluidounces of tersulphate of iron (*United States Pharmacopœia*) in about fifteen gallons of water, where they remain until the shade has become sufficiently dirty to suit the operator. Slightly changing the conditions, as, for instance, not allowing the rugs to dry, when mentioned in the process, or changing the strength of the solution and the time of exposure will give corresponding results in producing different shades, which may account for the difference of shades of such spurious goods as found in the market.

It is perhaps needless to say, that the cotton margin gives identical reactions with those observed in spurious goods found in the market. Treatment with a neutral solution of ferric chloride produces a greenish-black color. The iron can be seen by the rusty color of the ashes and additional tests if required. I do not anticipate that rugs so treated will show the same keeping qualities as the real antique rug. The fact that the colors in the rugs have not been changed but bodily taken out will certainly result in the almost complete destruction of the small quantity of color left, especially under the oxidizing influence of the iron salt introduced for the purpose of toning.

NEW YORK, July 17, 1893.

The UTILIZATION of GARBAGE.

By Dr. Bruno Terne.

[*A paper read at the meeting of the Chemical Section, held June 20, 1893.*]

The immortal Justus Liebig, the founder of agricultural chemistry, and, indirectly, by his teachings, the creator of the industry of artificial fertilizers, combined in himself the qualifications of a most eminent chemist and a far-sighted national economist.

He transformed the chemical doctrines of plant nutrition at once to available figures for the farmer to show him in clear and indubitable sentences the laws of nature which compel him to restore to the soil what he has taken from it in the form of the products of the field.

His classical *Chemical Letters* are a monument he has erected for himself which will endure as long as the conditions of this globe remain the same as they now are. As long as the human race lives, the fundamental laws requiring the restitution to the soil in available form of the constituents of the plants as laid down by Germany's most eminent agricultural chemist will be written in golden letters in the history of all civilized nations.

In centuries to come the classical works of Liebig will be revered as the revelation of science respecting the practice of agriculture.

In his forty-seventh letter, Liebig refers especially to the relation of the consumption of the great cities to the products of our farms. From each hectare of wheatfield, the farmer, from the return of an average harvest transports from his farm to the consumers, 4,000 pounds of grain containing seventy pounds of mineral substances, mainly phosphoric acid and potash.

The refuse of a city of 1,000,000 inhabitants will amount, in dried form, per annum, to 45,000,000 pounds.

The constituents of this powdered material are 10,300,000 pounds of mineral substances, mostly the mineral parts of

breadstuffs and meat, which contain no less than 4,580,000 of phosphatic salts.

The removal of this precious material (at the rate above-named) from the fields has been going on for centuries and only a small portion of it finds its way back to the fields.

It is folly to think that the loss of this material has had no detrimental influence upon the fertility of the soil.

I will quote from the tenth letter of Henry C. Carey, the American statesman and national economist, to the President of the United States. [J. B. Lippincott, Phila., 1858.]

"The national economical question is not how much we can produce but how much is returned to the soil of the products annually.

"Labor used to rob the soil is worse than labor thrown away. In the latter it is a loss to the present generation, in the former poverty for the coming generation."

The same system which Carey condemned, in the above citation, of a large export of material without corresponding restitution of plant food to the soil continues to be practised in the corn belt of the West, while the cotton belt of the South and the entire East have been compelled to yield to the inexorable law of nature, and must now restore food to the impoverished soil to raise their crops.

The zone subservient to artificial nutrification of the soil grows wider and wider from year to year, since the waste of plant food-material grows more serious as our population grows denser.

What Carey so incisively pointed out thirty-five years ago, is as true to-day as it was then, but only the stress of absolute necessity, or the prospect of financial gain, will suffice to alter the system involving the extravagant waste of plant food-material which is now the rule with us.

For the sake of convenience we pollute our rivers and choose rather to suffer the consequences of drinking polluted water than to adopt rational measures to save, for the enrichment of our fields, the products which the law of nature has provided for the very purpose.

Our antipodeans, the much-despised Chinese, are much better practical economists than their civilized brethren

In China, nothing is allowed to go to waste that is useful to the soil. The Chinaman's house is without the improved devices of the modern plumber, and his scent for nuisances may not be so highly cultivated as ours, but by his system of the strictest economy, he manages to keep up the fertility of his soil to so high a degree, that the vast empire, notwithstanding that it possesses the densest population on the face of the earth, is entirely independent of all other nations, not only for the breadstuffs and other food supplies required for the sustenance of its people, but also for the fertilizing materials needed for its soil.

The Chinese, with the instinct of self-preservation, have been doing for centuries what Liebig and his followers taught the civilized nations of the world in the beginning and middle of the present century.

To-day we have fleets engaged in transporting phosphoretic and nitrogeneous materials from continent to continent; the services of the miner and the skill of the chemist are required to supply this food-material to our exhausted fields.

The nitrate mines of Chile, the phosphate beds of South Carolina and Florida, of Belgium and Russia, the mountains of apatite rock of Estremadura and the deposits of the same material in Canada, the potash salts of Germany and Hungary, are drawn into the service of agriculture. One of the most gigantic branches of the chemical industry has been built up in order to balance the debit and credit page of the rational farmer in the records of his culture.

But in seeking for remedies that will preserve the fertility of our fields, it is a remarkable fact that a vast amount of waste material which lies right at our feet, is not given a thought.

It is true that all the more valuable waste materials, such as bones, tankage, cracklings, cottonseed meal, leather, hoofs, horns, etc., have a stable market. But the poorer and much more abundant materials have been, and are now, almost entirely neglected.

We will to-night direct our attention to the question of the possibility of utilizing the garbage of our city, which, at the present writing, is the subject of much discussion.

Until recently the garbage collected in this city has been used mainly as a feeding material for the fattening of pigs in the outskirts. For sanitary reasons, the Board of Health has banished the piggeries outside the limits of the county of Philadelphia. This is very commendable to free the city of a nuisance, which at the best was a very crude method of disposing of the material, and which, by the carelessness of those who make a business of it, certainly created a health-endangering nuisance; but the decision of the Board of Health made the disposal of the material very much more difficult than before.

The city of Philadelphia is divided into five districts for the collection of garbage. During the summer months, from June to September, the accumulation of a single district runs up to 100 tons per day, while in the other months of the year the daily output varies, and in the middle of the winter falls to twenty-five tons per day.

A general average for the whole year is about 250 tons per day for the whole city.

This estimate we can safely use for calculation of returns but not as a basis for the construction of a plant, for which the maximum figures will have to be taken.

For the first district, comprising all that part of the city south from South Street, from river to river, a furnace for the cremation of garbage has been erected, situated on Washington Avenue and Twentieth Street.

Unquestionably cremation is the most complete system for destroying all organic substances, and doubtless to the extreme sanitarian the only method that should be adopted.

But what about the economical results? The daily operation of the furnace requires labor and fuel, the product of a cremator is a small quantity of ashes and worthless at that. Four or five per cent. of ashes is all that remains of the garbage when incinerated.

The American Incinerating Company, with headquarters at Washington Avenue and Twentieth Street, has offered its product to the fertilizer trade. I have here a sample of these ashes which were sent to us. Our analysis yielded us:

Total phosphoric acid = 15·32 per cent. (= 33·88 per

cent. phosphate of lime), potash 0·25 per cent., soluble in water.

I was astonished to find so little potash but the intense heat in the furnace has driven off a part of the alkalies as chloride vapors, otherwise the analysis should show at least four times as much.

This ash, even with fifteen per cent. phosphoric acid, has a very low market value because natural phosphates in bags, and ground to the finest powder, can be laid down at our doors at $5 per ton.

The phosphoric acid of such low percentage is valueless for dissolving purposes because it will only yield practically a powder containing five to six per cent. of available phosphoric acid. This low product cannot be used for mixing fertilizers and it cannot be offered to the market when acid rocks containing thirteen to fourteen per cent. of available phosphoric acid are offered as low as $10 to $12 per ton.

The products of the cremating process, therefore, will never become a commercial article. The question then arises, Can the same sanitary requirements be reached in another way? Without doubt they can, and, at the same time, the valuable constituents of the garbage destroyed in the furnace can be saved.

The city garbage, embracing all the refuse from the table and kitchen, changes its qualities considerably with the season. Just now we are in the vegetable period and the results of my experiments represent about the lowest results obtainable.

The experiments I have made are not laboratory experiments, but practical manufacturing experiments, handling at a time from six to twelve tons of material. I have been in the fortunate situation of being able to utilize, at intervals, apparatus designed for other purposes but very well adapted for the purpose of these experiments.

There is no secrecy about the principle of rationally utilizing garbage, and there are no new processes involved for which enormous patent fees will have to be paid.

The process is divided in two main operations:

(1) The separation of the grease by extraction.

(2) The drying of the remainder to form directly a salable product.

The results I have obtained yielded me about seventeen per cent., on an average, of dry product from garbage tankage, a sample of which you have before you. This dry tankage is a very excellent fertilizing material. Its composition is:

	Per Cent.
Moisture,	4·41
Organic matter,	73·34
(including 4·3 per cent. NH_3)	
Mineral matter,	22·25
	100·00

On a smaller scale than that which could profitably be carried on in Philadelphia, garbage is utilized successfully in this way in several places. I have received from Detroit samples of fertilizer made from garbage with as high as 5·37 per cent. ammonia, 6·08 phosphoric acid; and, at another time, 3·76 per cent. ammonia, 3·36 phosphoric acid.

A specimen from Providence contained 3·55 ammonia, 3·38 phosphoric acid; from other places, 3·86 ammonia, 3·51 phosphoric acid.

A fair average analysis, showing the minimum and maximum of what we may export, is as follows:

	Per Cent.	Per Cent.
Ammonia,	3·50	4·50
Phosphoric acid,	3·	6·
(corresponding to phosphate of lime, 6·54, 13·28.)		
Water soluble potash,	0·25	0·50

At the present market price the unit of ammonia is sold at 2·60. This would give, for the low grade, a market value of $9.10 per ton; for the high grade, $11.10 per ton.

It is safe to say that at the present market these products will realize $10 per ton. I leave phosphoric acid and potash out of the calculation to give you the practical valuation.

This material is a most excellent fertilizer, not only chemically but also physically, and its usefulness in the manufacture of fertilizers is without limit.

The amount of garbage tankage produced from a ton of material as gathered up from the houses, placed at the low-

est percentage (viz: about fifteen per cent.), amounts to 300 pounds per ton. One hundred tons per day will give 30,000 pounds or fifteen tons daily.

Taking the daily average of one district, we will average seven and one-half tons, or 2,250 tons per year; and for the five districts, 11,250 tons, having a market value of $112,500.

Now, let us see what we restore to the fields in this amount of products.

The ammonia taken at four per cent. in one ton of the tankage contains eighty pounds of this important plant food, and 112,500 tons, or the amount of production from the garbage of this city should be equivalent to a saving of 9,000,000 pounds of ammonia, 9,000,000 pounds of phosphoric acid, and 500,000 pounds of potash.

All of this has been taken from our fields, and, if wasted or destroyed, represents so much loss to the community at large, but if this amount be regained and restored in proper form to the farm and garden it means so much saving. All of this amount must be restored from other sources in some way. If any waste material is worth saving it is surely the garbage of the cities, as I have endeavored to show.

There is another feature connected with this waste, viz: the regaining of the grease contained in garbage.

City garbage, at a low estimate, will yield three per cent. of a black grease, which you see in the samples before you. Even for this black grease, there exists a limited market at low figures for lubricating purposes (for car wheels). This black grease rarely contains much free fatty acid but it is by no means free from it. I have had samples containing over six per cent.

If the regular production should rise to such quantities as the garbage of the whole city will permit of producing, other uses must be found for this product, which, in the crude state has but a limited field of usefulness. There are ways and means known to the chemist, however, to improve this raw product, and the refined material made from it will readily find a market in competition with other greases.

The result of a chemical artifice of this kind, I take pleasure in introducing to your notice in the sample before

you. The method employed by me in this work is absolutely practical in respect of quick action, cheapness and positive results.

The grease stock so produced is very oily at 60° F. It yields about seventy to seventy-five per cent. of this very fine oil which will find a ready sale. This oil will prove a puzzle to the best expert in the analysis of oils, for it contains traces of all oils and greases which enter the kitchen. It will challenge the reliability of all the color tests, the iodine numbers, etc., but in spite of its evasion of the methods of a Mailliau and Benedikt, it will find an excellent market.

The refined grease is a very fine soap stock, and a very crude product of a test in that direction I have with me. This soap is made solely from the same grease you have before you.

The rational mode of disposing of the city garbage is as simple as anything can be.

First, to gain all the grease, we must apply practical methods of extraction by known solvents; then, to save the fertilizer materials, we must employ the most rapid and economical methods to expel the eighty per cent. of water contained in the material.

Small amounts are easily handled; the difficulty arises when such enormous quantities stare one in the face. It is not, therefore, so much the chemical processes employed as the proper disposition of the plant, which must be well understood.

The stock delivered at the works must disappear in the process, on its arrival, and must never be permitted to rest for a moment until, after forty-eight hours, it is ready to be filled into bags for shipment in the form you see before you in this sample. It is no more difficult to handle the enormous quantities of garbage than it is to handle the animal refuse of our city.

My experience of many years in handling materials of this kind in enormous quantities, first in Chicago, and since 1877 in this city, as the chemical manager of the largest works of its kind, permits me to speak advisedly on this

subject, and I am prepared to stake my reputation as a technical chemist on the assertion that the utilization of our city garbage can be carried on as a financially successful operation for the saving of the valuable materials contained therein. How important the solution of this question is for the city of Philadelphia is well illustrated by the constant discussion of the subject in the daily papers.

Cremation, as I have shown, produces, at considerable expense, a valueless product. The rational chemical process yields, at no more cost, products which make a large figure in the housekeeping of a community.

Should we cast aside the warnings of an economist like Carey? Shall the teachings of Liebig and of all the prominent agricultural chemists of all nations have been in vain? I trust not, and believe not.

In this century of progress, with our knowledge of chemistry, and with the most complete machinery at our disposal, it seems to me like a lapse into barbarism to destroy this most valuable material simply for the purpose of getting rid of it, while at the same time, we are eager to obtain these very same materials for our fields by purchase from other sources.

There is no doubt in my mind that this question of the disposal of our garbage can be solved by careful consideration of all points, by practical business men, to the advantage of the city authorities and the contractors for this work, to the fullest satisfaction of the health authorities, and to the benefit of the farmer.

Capital intelligently invested should be productive, not destructive. Instead of spending thousands of dollars for the erection of crematories to destroy, let us erect sanitary chemical works to preserve, this valuable material. There can be no danger to the public health in the conduct of a rational system for the utilization of garbage. All microbic carriers of contagious sicknesses are destroyed by a temperature of 212° F., and this dry product you have before you is as harmless to the public health as the flour in the barrel.

My desire and expectation to-night, in making this

presentation of an important industrial and sanitary problem, is to receive the endorsement of the Section, and later on, that of the Institute, to have you condemn the destruction of these valuable waste products, and approve, as the only right solution of this question, the preservation of these products displayed before you by a rational process of manufacture such as that indicated above.*

ARTESIAN WELLS.

By Oscar C. S. Carter.
Professor of Geology and Mineralogy, Central High School, Philadelphia.

[*Read at the stated meeting of the Chemical Section, held March 21, 1893.*]

Within the last few years a great many artesian wells have been drilled in Pennsylvania to obtain pure drinking water for towns, villages and farms, and also for various manufacturing and industrial purposes, such as the manufacture of artificial ice, the brewing of beer and for use in steam and locomotive boilers. The two principal questions to consider in artesian water are the quality and the quantity. First, as regards the quality, there can be no doubt that water which filters through from 200 to 500 feet of rocky strata is free from all deleterious organic matter. Disease germs, which sewage in river water renders so common, are unknown in artesian water unless the well be drilled in a thickly populated district or be improperly cased. Artesian water comes to the surface clear and sparkling and is

* The very able report on the above paper, which appeared in the *Public Ledger*, seems to have given to some persons interested in this question, the wrong impression, that it was presented in the interest of the company with which I am connected. Such is not the case.

This question, like any other question of interest to the company, has been fairly examined into by its chemical manager, but the company, for business reasons, would not undertake the utilization of garbage.

The chemical manager, therefore, was at liberty to make use of the results of his experiments for the benefit of the public at large, and did so after consultation with the president of the company and with his approbation.

B. T.

never muddy from clayey matter or dirt held in suspension. The geological formations of Southeastern Pennsylvania contain prolific water-bearing strata. Wells drilled in the sandstones, clay slates, and shales of the trias, in the mica schists and gneisses of the Philadelphia group, in the Silurian limestone and in the Potsdam sandstone, generally yield an abundance of water; occasionally, a barren locality is met with, but this is rarely the case. It would be impossible to lay down any hard-and-fast rule as to which formation furnishes the most abundant supply of water; an examination of the records of the accompanying wells will give some idea. The new red sandstone shales and slates and the mica schists of the Philadelphia group yield an abundant supply of water. The Silurian limestone in this vicinity often dips steeply, but gives a good supply. Thus far, wells drilled in the Potsdam sandstone have not yielded as much water as the above formations, although a good supply is obtained. It may be stated as a rule that those stratified rocks which are highly jointed, fissured and porous, furnish many easy channels for the passage of rain-water to strata situated at great depths, and that beds of clay, clay slates, fine-grained sandstones, quartzites and compact mica schists make very good confining beds. The quantity of water furnished by deep wells near Philadelphia is enormous. The well at Lansdale, Montgomery County, can yield 288,000 gallons per day; the two wells at Jenkintown, 216,000 gallons each per day; the well of the Oriental Bath Company, 1104 Walnut Street, 144,000 gallons per day. One popular error seems to have gained a foothold, that a well is of little interest unless it be a deep one, and that the deepest ones furnish the most water. Many lose sight of the fact that the object of drilling a well is to obtain water, and when an abundant supply is reached at a moderate depth it is a useless expense to drill deeper. Shallow wells often yield enormous quantities of water. A drilled water well only 35 feet deep and 6 inches in diameter, at Washington Square gives over 1,500 gallons per hour and does not lower no matter how much is pumped. (See *Proc. Amer. Philos. Soc.*, May 1, 1891.)

What kind of Rocks yield Hard Water and what kind Soft?—Whether a water be hard or soft depends mainly upon the composition of the soil and rocks through which it filters. Water that passes through calcareous or magnesium rocks of great thickness will probably be hard, while water that passes through rocks composed of silica, alumina, iron, potash or soda will probably be soft. The great deposits of limestone, marble, gypsum and other calcareous rocks, as well as the magnesian rocks, such as dolomite, chlorite and talcose schists would then yield hard water. The granites, gneisses and many sandstones and slates would furnish soft water. This, in the main, is true, although there are some exceptions which local conditions modify. Some sandstones will yield soft water, while other sandstones furnish hard water; it depends mainly upon the cement which binds the grains together; if the cementing material be carbonate of lime or sulphate of lime the water will probably be hard, especially if the well be of great depth and the water be long in contact with the rocks. If, on the other hand, the cementing material be feldspar, such as orthoclase or albite (not labradorite), or even gelatinous silica, the water will probably be soft.

In England, many determinations of the hardness of spring and artesian water from different geological formations have been made; so that it can be safely predicted what kind of water an artesian well will yield when it is drilled in the Devonian, in the Silurian limestone, in the new red sandstone, or in the chalk.

DEEP ARTESIAN WELL WATER (*England*).

	Hardness.	
Water from Devonian sandstone,	17°	Hard waters.
Water from magnesian limestone,	43°	
Water from new red sandstone,	17°	
Water from chalk,	27°	

Water from granite and gneiss, soft.
Water from Silurian sandstones, slate and shales, soft.
Water from millstone grit, soft.

Water which flows through calcareous channels is hard, while that which flows through silicious rocks is soft.

The same facts are noticed in the artesian wells of Pennsylvania. Artesian water from the new red sandstone is generally hard, though not so hard as the English new red water. An analysis of a new red water from a well 102 feet deep, at Norristown, gave me 11°·8 of hardness; the hardness was mostly due to carbonate of lime, although some sulphate was present. The magnesian limestones of Pennsylvania furnish hard water; this is noticeable at Reading, Pa., where a limestone stream empties into the Schuylkill and neutralizes the water from the coal mines, which is charged with sulphate of iron and a little sulphuric acid. When the streams meet, sulphate of lime is precipitated, and also carbonate of iron, which decomposes to ferric hydrate, and can be seen as a brown stain on the dam near the city.

Many of our deep marble and limestone quarries of Montgomery County, Hitner's, Henderson's, Graver's, Rambo's and others, are always partially filled with water; this is not rain-water because at Graver's quarry the rotary force pumps were running eight months of the year night and day, with an eight-inch and four-inch discharge pipe and the quarry was not nearly pumped dry. This water filters through the limestone and is not always hard because at Rambo's quarry the water was used in the boilers and the engineer reported no scale or precipitate present. Deep artesian water from clay slates and shales of the trias is often a little hard. (See analysis of boiler scale from Lansdale artesian well water.) Deep artesian wells in the mica schist and gneiss of Philadelphia and vicinity furnish water of slight hardness; this hardness disappears when the well has been in use for several months and is not sufficient to interfere with its use for industrial purposes. The purest and clearest water in this vicinity would be obtained by drilling in the syenite and granitic rocks. The water that issues from the granitic rocks and hills above Lafayette Station is of exceptional purity and is free from organic matter.

Rate of Drilling different Rocks.—The rate of drilling through the various rocks, such as granite, syenite, mica schist, hornblende schist, sandstone, limestone, clay slates

and shales, is a very important and interesting feature as a saving of time and expense depends on it. There are several factors that enter in the problem of rapid rock drilling, the most important perhaps are the hardness and compactness of the rock, and the weight, temper and drop of the drill. The most difficult rocks to drill through are trap, quartzite, compact fine-grained sandstones, certain clay slates, granites, syenites and compact hornblende schist, obsidian, etc.

The softer rocks, such as talcose and chlorite schists, serpentine and other magnesian rocks, limestone, dolomite, hydro mica schists and many coarse-grained sandstones are readily drilled through. The following table will show the thickness of rock pierced by a chisel drill 20 feet long 5⅝ inches in diameter, weighing 700 pounds, guided so as to make a round hole:

Locality.	*Rock.*	*Rate.*		
Duffield's farm, on Stony Creek, near Belfry, . . .	Clay Slate (Trias),	4½	feet drilled in	10 hours.
Ice Company's well, Norristown, ...	Sandstone (Trias),	5	"	"
Kunkle's farm, Valley Green Road, near Flourtown,	Limestone (Silurian),	5½	"	"
Wheadley's farm, Chester County, ...	Hydro Mica Schist,	7	"	"
Wm. Janeas farm, near William Station, ...	Sandstone (Potsdam),	10	"	"
Roberts well, Spring Mill, ...	Sandstone (Potsdam),	18½	"	7 hours.

The Potsdam sandstone at the above localities is not like the hard edge hill rock and conglomerate, but on the contrary is soft and micaceous, which accounts for the rapid progress. When the Schuylkill Valley Railroad was built the Pennsylvania engineers found the hardest rock they had to drill along the Schuylkill was the trap rock at Conshohocken; the next hardest was the syenite, below Spring Mill. One contractor forfeited his contract on that account; next came the mica schist, then the sandstone, and last the limestone. The minerals which compose a rock may be very hard, and yet the cementing material may hold the grains so loosely that the drill will make rapid progress through the rock. Sandstone, when composed entirely of silica, or when the cementing material is gelatinous, silica as in quartzite, is extremely hard to drill, but when the cement which binds the grains is feldspar, which decomposes readily, then the grains are loosely held, and the rock is readily drilled. The hardness of a steel drill is over 7,

while the hardness of the minerals which go to make up the great mass of rocks is under 7. Feldspar, 6; hornblende, 5 to 6; augite, 5 to 6; mica, 3; limestone, 3; dolomite, $3\frac{1}{2}$; talc, 1; quartz, which has a hardness of 7, is the most abundant mineral, and rapidly wears and destroys the temper of a drill. Coarse-grained rocks are more readily drilled than fine-grained. Steeply-dipping strata are more difficult to drill on account of the trouble in keeping the drill vertical. Sayer's well, at Fox Chase, was drilled in the mica schist. There was one vein of rock in this well, probably quartz, only seven inches in thickness, that took eighteen hours to drill, and required twelve sharp drills in that time.

Cryolite in a Philadelphia Artesian Well.—Wm. W. Matos, a student of the Central High School, presented me with two specimens of minerals, which he said came from an artesian well; on examination, they proved to be cryolite. One specimen contained several rhombohedra of siderite, which frequently accompanies Greenland cryolite. The other specimen contained, besides cryolite, some siderite, galenite, quartz, and a little copper pyrites, all of which are found in the cryolite of Ivigtuk, Greenland. The specimens were about the size of common marbles. On telling him that it was unusual to find cryolite except in Greenland and a few other localities, and that there must be some error he volunteered to see the driller again and question him closely. The specimens are without doubt cryolite. The exact locality of the well is about Fiftieth Street and Columbia Avenue, on land belonging to Pennsylvania Railroad. The well was drilled by Brush & Co., a New York firm. On asking why the specimens were not ground to powder by the drill, he said that when drilling at a depth of 280 feet they struck a water crevice, and the drill fell a short distance and broke off some fragments of the surrounding rock, these were drawn up by the sand pump, and the specimens of cryolite were among them. The driller says the cryolite was broken into several small pieces, and estimates the depth at which it was broken off to be about 280 feet. He thinks the vein is only a few inches in thickness. The well was

drilled to obtain water for the locomotive engines of Pennsylvania Railroad Company. The rock passed through was mica schist and gneiss, and at and around 280 feet the driller pronounced the rock very hard. The diameter of the well is six inches, and they quit drilling at a depth of 350 feet. The water rises in the wall to within twenty-five feet of the surface of the ground, and on pumping without a force pump, and using only a small engine pump, the well yields 2,400 to 3,000 gallons per hour; it would give much more with an improved pump. No specimens were found below 280 feet. The finder was Mr. Richard Wickward.

Cost of Artesian Wells.—The price of drilling is about $2 per foot in Montgomery County for wells 6 inches in diameter and from 100 to 200 feet deep: this is independent of the character and hardness of the rock. A hard clay slate requires twice as long a time to drill as a loose mica schist or a decomposed sandstone, and yet it would be a difficult matter to regulate the price according to the hardness of the rock and the difficulty of drilling, because in many wells alternate beds of sandstone, red shale and sometimes clay are met with. An examination of the table on the rate of drilling will show that the rate with which different rocks are drilled varies greatly yet the same rate per foot is charged for granites, syenites, mica schists, sandstones and limestones. I have known the drillers to make the unusually slow progress of six inches in ten hours when a very hard quartzite was being drilled. Sometimes they are delayed more than a month over the usual time required to drill a well, by some unusual obstruction, such as a hard, steeply-dipping stratum, when it is almost impossible to keep the drill vertical and the well straight; occasionally, the tools become loosened and drop down the well, and a week or more is wasted in grappling for them. The six-inch iron pipe (internal diameter five and five-eighths inches), which is used to line the well, varies in price from forty to fifty-five cents per foot. Most of the wells in Montgomery County, which will be referred to later, and whose depth varies from 50 to 200 feet, were drilled at the rate of about $2 per foot. The driller of these wells guarantees water, and

promises to finish the well and test it or no pay. If the water should be chalybeate or colored, which is rarely the case, he agrees to pump it until it becomes clear.

In Philadelphia, the charges vary and contracts differ in terms. Some drillers contract, for a certain specified sum, to drill a well that will furnish a certain amount of good water per minute, generally fifty or seventy-five gallons. The contract price includes everything, casing, coal and testing.

Many of the Philadelphia wells are double-cased; the first pipe put down is an eight-inch pipe; then a six-inch pipe is put down inside of this, and the space between the two is filled with hydraulic cement.

Some contracts have been made at the rate of $4 per foot, this includes the drilling, casing, testing and everything connected with the well.

Other contracts have been made at the rate of $2.75 per foot for drilling down to 500 feet and $3 per foot for drilling below a depth of 500 feet; this does not include the iron pipe for casing, but only the drilling.

Deep Artesian Wells in the Red Shales and Clay Slates of the Triassic.—At Lansdale, Montgomery County, Pa., on the line of the North Penn Railroad, three artesian wells were drilled for Effrig & Son, pork packers.

The first well is 159 feet deep, the second one 376 feet, and the third and latest one is 611 feet deep. These wells are within fifty feet of one another. The last well has 259 feet of iron pipe as casing, and, on pumping with a small pump, gives seventy gallons per minute; with a larger and improved pump, it will give 200 gallons per minute, or 288,000 gallons per day: the supply seems to be practically inexhaustible. The water rises to within 140 feet of the top of the well.

No systematic record of the borings was kept. Rock was first struck at a depth of twelve feet.

The drill passed through alternate layers of red shale, red sandstone, blue clay slates, and black carbonaceous slates. A small bed of carbonaceous slate, six or eight inches thick, was struck, and also a bed of the same character, twenty

feet thick. This last bed was found at a depth of forty feet from the surface. Under this bed of black clay slate was a deposit of what they supposed to be cannel coal, but it was evidently a shale or slate, very rich in carbon.

The water from these wells when used in boilers deposits a scale, which I analyzed and found to consist of $CaCO_3$, $MgCO_3$, $CaSO_4$, $MgSO_4$, NaCl, and a trace of iron, sufficient to color slightly the scale. The water is not very hard, the hardness being mainly due to $CaCO_3$, which makes up the bulk of the scale. This hardness of the water is only temporary and will disappear when the well has been in use for several months and continually pumped, as fresh water takes the place of that which has long been in contact with rocks and which has dissolved out the salts of lime and magnesia. This I have noticed to be the case in several wells; when the well is first drilled, the water is hard enough to require a small amount of soda in the boiler as an anti-incrustator. It acts by precipitating the lime and softening the water. After the well has been pumped for several months the hardness disappears and the anti-incrustator is dispensed with.

The 611-foot well was six months in drilling. The drillers complained that the clay slate was very hard and contained much quartz, which kept them drilling much longer than usual.

The above facts correspond well with those obtained from another well drilled a few miles from Lansdale on, the Duffield farm, between Custer and Belfry, on the Stony Creek Railroad. (See *Proc. Amer. Philos. Soc.*, vol. xxix, May 25, 1891.) In this last well, the bed of very black rock, supposed to be coal, was found at a depth of about forty feet from the surface; this is the same depth as the Lansdale bed. I understand the same bed of coaly rock was found when Mr. Rozenzi drilled the very deep well in Bucks County for gas. Another firm drilled the Duffield well, and they made the same complaint about the hardness of the rock. One bed in particular, that was supposed to be quartzite, was so hard that only six inches of it could be drilled in ten hours. The

Duffield well is only sixty-five feet deep and yields but sixty gallons per hour, while the Lansdale well yields 200 gallons per minute. In these tightly-packed clay slates an abundance of water is found only at great depths.

BOOK NOTICES.

William Gilbert, of Colchester, Physician of London. On the loadstone and magnetic bodies, and on the great magnet, the earth. A new physiology demonstrated with many arguments and experiments. A translation by P. Fleury Mottelay. New York: John Wiley & Sons, 53 East Tenth Street. 1893.

The publishers are to be congratulated on the appearance, in admirable form, of a translation of the classic work of Gilbert, at the hands of one so competent, by reason of his special familiarity with the subject, as Mr. Mottelay. The task which the translator had to perform was one which required the exercise of the severest critical acumen to render into modern idiomatic English the often obscure meaning of the author, and a thorough familiarty with the modern aspects of electrical theory and practice. That the author has done his work well, is demonstrated by the extremely flattering reception with which it has been received by specialists everywhere. W.

The Mineral Industry. Its statistics, technology and trade, in the United States and other countries, from the earliest times to the end of 1892. Vol. I. Edited by Richard P. Rothwell, editor of the *Engineering and Mining Journal.* New York: The Scientific Publishing Company. 1893.

For a number of years the *Engineering and Mining Journal* has engaged in the collection of statistics relating to the leading features of the mineral industry, which were published annually in the form of a statistical supplement. These supplements for a series of years constituted a valuable source of information to those interested in these important industries, from which to obtain reliable advices respecting their condition; and, from the thoroughness with which the work was done, these supplements came to be regarded as standard publications, whose appearance was eagerly looked for. They were all the more welcome from the fact that they constituted the only source of early information accessible to those engaged or interested in the great mineral producing industries. The annual volumes issued under the direction of the Statistical Bureau of the United States Geological Survey, have, by force of circumstances, invariably been so long delayed, that when they appeared their contents, though of great value for purposes of comparison and future reference, were of comparatively little importance for immediate use to business or professional men.

Encouraged doubtless by the very flattering reception accorded to the statistical supplements, the *Journal* conceived the ambitious project of extending their scope, and, beginning with the year 1892, has begun the publication of an annual volume in book form, comprising a complete summary of the

statistical position, technology and trade of the mineral industries of the United States and other countries. The first volume of this interesting and valuable publication is before us, forming a substantial quarto of over 600 pages.

Each of the important subjects embraced in the volume is treated in a separate chapter, under the signature of a competent specialist, and the entire collection of contributors has had the advantage of the editorial revision of Mr. Rothwell, whose skill and long experience in work of this kind need no praise at our hands.

Only those who have been engaged in statistical work will be able to appreciate fully the amount of labor involved in the work of collecting and revising the vast array of facts and figures contained in a volume of this character, and the additional labor involved in its preparation and publication within a few months of the close of the year to which they relate, a circumstance which greatly enhances its value to the professional and business community. The volume is a surprising and gratifying evidence of journalistic enterprise on the part of its publishers, and reflects the highest credit upon all who have contributed to its make-up.

We are assured that it is the purpose of the publishers to issue this volume annually. It is by far the most complete and valuable publication of its class that has ever been issued, and if the declared intention of its publishers is carried out, it will constitute a work of reference which will be absolutely indispensable to all who are interested in the subjects of which it treats. W.

Knots, Splices, Hitches, Bends and Lashings. Illustrated and described. By F. R. Brainard, Ensign, U. S. N. New York: Practical Publishing Company, 21 Park Row. 1893. (Price, $1.)

This little manual explains and illustrates very satisfactorily the various forms of knots, splices, lashings, etc., which comprise so important a portion of the mystery of the art of the seaman, canoeist, hunter, rigger, builder and mechanic, and can be usefully consulted by all who wish to inform themselves of the subjects of which it treats. In addition to the descriptive and illustrative portions, the work contains a useful set of tables of hemp, and iron- and steel-wire rope, and a dozen pages of definitions of technical terms peculiar to the several arts and crafts above-named. W.

Valve Gears for Steam Engines. By Cecil H. Peabody. New York: John Wiley & Sons. 1893.

The present work employs both the analytic and graphic methods for studying the distribution of steam, using the Zeuner diagram.

After an analysis of the effect of the plain slide valve, the effect of shifting eccentrics, link-motions, radial and double valve gears are examined, special attention being paid to the methods of compensating for the inequalities introduced by the oscillation of the connecting-rod. The last chapter is devoted to a study of those valve gears which effect the cut-off by a disengaging of the valves from the valve-moving mechanism, permitting dropping weights to close the valves. H. B.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXVI. OCTOBER, 1893. No. 4

THERMAL ANALYSIS OF A "TANDEM" COMPOUND ENGINE.

By R. H. THURSTON.

In a recent paper, "On the Economics of 'Automatic' Engines," the writer developed at considerable length the principles involved in the study of the thermal distribution in such engines. He illustrated his methods by the computation, from data found by earlier experiments, now familiar to all interested in the subject, and known to be sensibly accurate, of the quantities of heat and power utilized and wasted under specified conditions of operation, such as are usual with this class of machines, giving a tabulated statement of the amount of heat-energy supplied, the quantity utilized by conversion into dynamic energy, that wasted as heat by conduction and radiation, and that lost by internal transfer without transformation and by

other than thermo-dynamic and necessary waste.* In the present paper, the writer proposes to show what is this distribution in an engine of familiar and representative type in good standing among machines of its class, as determined by a careful and fairly complete trial, made by the methods which the writer has been accustomed to employ and including the system of comparative analysis based upon the original work of Hirn and of Dwelshauvers-Dery, such as must always be employed when seeking to ascertain the nature and extent of those losses and wastes which distinguish the ideal and real engines.†

As remarked in the paper above referred to:

"The exact expenditure of heat, steam and fuel under specified representative conditions of this case, including steam-pressure, back-pressure, ratio of expansion, and boiler-efficiencies, can be computed for the thermo-dynamic, ideal, case; and, knowing the magnitude and conditions of physical operation of the engine, friction included, its wastes of energy, whether thermal or dynamic, can be very closely obtained by computation, and these wastes being added to the total thermo-dynamic expenditure, the gross outlay of energy becomes known and the economical problem can be solved." The following was given in illustration of these methods as determined for an "automatic" simple, condensing, engine, rated at ten to fifteen horse-power; having a cylinder six inches in diameter and eight inches stroke of piston, a speed of 280 revolutions a minute, and proportioned for a steam-pressure of 100 pounds. Compression was assumed complete and leakage insensible.

The demand for heat and steam was computed on the assumption of the data given below; the conditions as to waste being illustrated in the Sandy Hook experiments of 1884.‡ External wastes were assumed to average 0·5 B. T. U. per square foot of exposed surface, and per degree range of temperature from atmospheric—here taken as 100°

---

* *Jour. Franklin Inst.*, Oct. 1892.

† *Manual of the Steam Engine*, part i, chaps. v, vi.

‡ *Ibid.*, chap. v, § 129, p. 501.

F. Internal wastes were taken as a fraction of the total steam supplied,

$$w = a / d \cdot \sqrt{r\,n}$$

where the coëfficient $a = 4$ in the case assumed to be fairly represented of that here considered: d is the diameter of cylinder in inches, r the ratio of expansion, and n the number of revolutions per *second.* Friction wastes were taken as giving an efficiency of engine of 0·85.* J is taken as 778. The following are the data:

DATA.

$p_1 =$	75	95	115	135	155′
$p_3 =$	5	5	5	5	5
$r =$	1·6	2	4	8	16
$c = \frac{1}{r} =$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{16}$

Pressures were measured from absolute zero.

The thermo-dynamic effect of the steam was computed by the equations of Rankine.†

The results of those computations are presented, in part, in the accompanying table.

These computations for the ideal case show the consumption of steam under the specified conditions of pressure and cut-off to vary from a minimum of about eleven pounds per horse-power and per hour, at 155 pounds absolute pressure, to fifteen and one-third at the best cut-off for seventy-five pounds. But the introduction of the wastes produced an entirely different showing, and, for this case, the minima were found at expansions approximating

$$r = 0·5 \sqrt{p}$$

or from one-seventh at 155 pounds to one-fourth, nearly, at

---

* *Manual of the Steam Engine*, part i, chap. v, § 132–134.

† *Rankine's Prime Movers; Thurston's Manual*, p. 398; and chap. v, § 137.

seventy-five pounds above a vacuum, initial pressure in the cylinder; while the steam consumption became about

$$w = 250 \div \sqrt{p}$$

ranging from twenty-three to twenty-eight pounds per indicated horse-power per hour, and twenty-seven to thirty-three pounds per dynamometric horse-power. These figures are not large for the size and kind of engine taken in illustration of the method intended to be exhibited in the paper quoted; but they may be taken as representative of those to be expected with ordinarily good practice. With larger, faster, or better designed, and especially better protected engines, wastes may be reduced somewhat below those stated above and correspondingly nearer approximations effected to the goal sought by the engineer in designing economical engines—*i. e.*, to the performance of the ideal machine.*

In the case here to be presented, the engine is a compound, is much larger and more powerful, and affords better opportunity to effect this approximation. Its dimensions are:

DIMENSIONS OF ENGINE.

Diameter of high-pressure cylinder, . .	12	inches.
Diameter of low-pressure cylinder, . . .	20	inches.
Length of stroke (nominal), ...	14	inches.
Length of stroke (measured), ...	13·97	inches.
Length of stroke (measured), ...	1·164	feet.
Diameter of piston rod, ...	1·9375	inches.
Area of high-pressure piston, head, . . .	113·098	square inches.
Area of high-pressure piston, crank, . .	110·149	square inches.
Area of low-pressure piston, head, . . .	311·211	square inches.
Area of low-pressure piston, crank, . . .	311·211	square inches.
Piston displacement, high-pressure, head,	·91425	cubic foot.
Piston displacement, high-pressure, crank,	·89042	cubic foot.
Piston displacement, low-pressure, head,	2·51575	cubic feet.
Piston displacement, low-pressure, crank,	2·51575	cubic feet.
Clearance, high-pressure cylinder, head,	·15716	cubic foot.
Clearance, high-pressure cylinder, crank,	·14718	cubic foot.
Clearance, low-pressure cylinder, head,	·31422	cubic foot.
Clearance, low-pressure cylinder, crank,	·31925	cubic foot.

* *Rankine's Prime Movers; Thurston's Manual*, p. 398; and chap. v, § 129–131.

Clearance, per cent. of stroke, high-pressure cylinder, head,	17·50
Clearance, per cent. of stroke, high-pressure cylinder, crank,	16·20
Clearance, per cent. of stroke, low-pressure cylinder, head,	7·40
Clearance, per cent. of stroke, low-pressure cylinder, crank,	7·60
Volume of receiver-space,	1·1455 cubic feet.
Volume of space in pressure-plate,	·12819 cubic foot.
Volume of space in pressure plate, per cent. of stroke,	5·09

The design and arrangement of the engine is shown well in the plate exhibiting the method of fitting up for trial, and need not be here described.* It was built by the inventor, Mr. A. L. Ide, and is a "tandem compound" of the style known to the trade as "the Ideal." The computations of probable wastes, on the assumed basis previously taken, of correspondence with those of the Sandy Hook experiments, would give figures, reduced to expenditures per horse-power and per hour, about one-half those of the smaller engine above referred to, with its six-inch cylinder.† and would, on that basis and with ten per cent. friction, be as follows:

At the lowest pressure, 75 pounds, with the engine alluded to, maximum economy of steam and fuel was found at a cut-off very near $\frac{7}{32}$, or a ratio of expansion of about 4·5, when the dynamometric power was taken, or at about a cut-off of 0·2 and $r = 5$, on the basis of indicated power. These figures became about 3·16 and 5 at 95 pounds, $\frac{11}{64}$ and 6 at 115, $\frac{5}{32}$ and 6·4 at 135, and $\frac{9}{64}$ and 7 when the pressure was 155 absolute, or 140 pounds by gauge. (See *J. F. Inst.*, Oct., 1892.)

The minimum cost of power, in steam consumed, remains not far from the cut-offs identified for the first representative case; but the computed weights demanded are reduced very considerably by the fact that the wastes are but about

---

* For details of method, see *Thurston's Engine and Boiler Trials*, or *Carpenter's Experimental Engineering*.

† See *Manual*, chaps. v, vi.

EXTRA-THERMO-DYNAMIC WASTES.

*Total Consumption of Steam.**

r	Cut-off.	Pressure, Pounds per Sq. In.	Steam per I.H.P. per Hour (Ideal) *W*.	Total Waste, Pounds per I.H.P. and per Hour.	Total Consumption, Pounds per I.H.P. and per Hour.	Same per D.H.P. Machine Eff., 0·90.
16	1-16	75	*15·85*	11·5	27·35	30·6
8	1/8	75	*15·32*	7·5	*22·82*	*25·4*
4	1/4	75	*16·72*	5·5	*22·22*	*26·7*
2·7	3/8	75	*18·48*	5·3	*23·78*	*26·4*
2	1/2	75	*21·44*	5·3	*26·74*	*29·7*
1·6	5/8	75	*24·76*	5·2	*29·96*	*33·3*
16	1-16	95	*12·74*	8·7	21·44	23·8
8	1/8	95	*13·21*	6·2	*19·41*	*21·6*
4	1/4	95	*15·42*	4·8	*20·26*	*22·5*
2·7	3/8	95	*17·72*	4·7	*22·42*	*22·7*
2	1/2	95	*20·34*	4·6	*24·14*	*27·0*
1·6	5/8	95	*23·11*	4·6	*27·71*	*30·8*
16	1-16	115	*11·91*	8·0	19·91	22·1
8	1/8	115	*12·68*	5·9	*18·58*	*20·6*
4	1/4	115	*14·97*	4·8	*19·77*	*22·0*
2·7	3/8	115	*17·35*	4·6	*21·95*	*24·4*
2	1/2	115	*19·88*	4·5	*24·38*	*27·1*
1·6	5/8	115	*22·60*	4·0	*26·60*	*29·9*
16	1-16	135	*11·38*	7·5	18·88	21·0
8	1/8	135	*12·32*	5·6	*17·92*	*19·9*
4	1/4	135	*14·67*	4·7	*19·37*	*21·5*
2·7	3/8	135	*16·96*	4·4	*21·36*	*23·7*
2	1/2	135	*19·54*	4·4	*23·94*	*26·5*
1·6	5/8	135	*22·25*	4·4	*26·65*	*29·6*
16	1-16	155	*10·98*	7·1	18·08	20·1
8	1/8	155	*12·05*	5·5	*17·55*	*19·5*
4	1/4	155	*14·41*	4·6	*19·01*	*21·0*
2·7	3/8	155	*16·72*	4·4	*21·12*	*21·1*
2	1/2	155	*19·28*	4·3	*23·58*	*25·1*
1·6	5/8	155	*21·95*	4·1	*26·05*	*28·9*

* The mean effective pressure here found is as before, not far from

$$p_2 = 6 \sqrt{p_1}$$

and the pressure to be adopted by the designer for such cases will be greater, perhaps not far from

$$p_1 = 5 \sqrt{p_1}$$

gauge-pressures being taken; while the power of the engine is, for the best cases,

$$I.\ H.\ P. = 0{\cdot}025\, d^2 \sqrt{p_1}, \text{ nearly,}$$

slowly rising with increasing pressure; d being here the diameter of the large cylinder,

$$D.\ H.\ P. = 0{\cdot}022\, d^2 \sqrt{p_1}, \text{ nearly.}$$

one-half those previously found for the smaller engine. These wastes averaged eight or nine pounds for the latter, and are about four and one-half for the former. It will be interesting to now compare these computed results with the actual performance of the machine. A single trial will suffice, as it will establish the constants for the engine, and the behavior of the machine for other conditions than those of the trial may be then computed with satisfactory approximation, as required or desired.

The whole work of preparation and management of the trial was undertaken by Mr. F. P. Ide, one of the computers of the data given by the writer for the cases above described, and the methods employed were those customarily carried out in regular work in the Sibley College laboratories, where similar purposes are in view. It is here presented somewhat fully, both as illustrating those methods and as giving interesting data from this just now peculiarly interesting class of machine, the "high-speed engine" adopted so generally in the distribution of electrical energy. The details of the machine need not be here given, as they are foreign to the purposes of this paper.* It is only necessary here to say that the machine is carefully balanced, has good provisions for free lubrication, and, in the only case in which the writer has had extended experience with it,† has shown itself an excellent example of its class.

The arrangements of the apparatus will be seen by reference to the engraving.

The load was furnished by *two* "Prony" brakes. The brake-wheels were cast with flanged edges, so that water might run upon the inside of the pulleys. A one-inch pipe carried water to the wheel, while a one and one-half inch pipe carried it away. The supply pipe was reduced to about

---

* For details, see *Manual of the Steam Engine*, part i, art. 35, p. 142.

† An engine of this kind was built in the shops of Sibley College, Cornell University, and has now for several years, done good work, driving dynamos for experimental work in the Department of Physics. The trial to be here described was the first complete investigation of its kind made with the type of engine in question, and had peculiar interest for the writer and for the builder of the engine for this reason.

one-half inch at the end, to act as a nozzle and throw the water into the wheel at the velocity given its rim, so as to avoid splash.

These wheels were 6 feet in diameter, and of 14-inch face.

The quantity of heat to be removed was approximately known, and accepting the constants given by Box, we have as the amount which may be conducted through the rim, for the surface, eleven square feet, and a thickness of two inches:

$$\begin{aligned} U &= (233 \times 11 \times 100) \div (2 \times 60) \\ &= 2136 \\ &= 1{,}661{,}808 \text{ (foot-pounds per minute)} \\ &= 50{\cdot}3 \text{ horse-power.} \end{aligned}$$

It was found, however, that double this power could easily be absorbed. It is probable that nearly one-half the heat generated was dissipated by contact with the air, and by radiation, permitting the brake to easily absorb 100 horse-power.

A surface condenser was used, rated at sixty horse-power. It had 150 feet of cooling surface. To free the condenser a power pump, with 5-inch cylinder and 5-inch stroke, was employed. It was belted to an 18-inch pulley on the engine shaft. The speed was one-third that of the engine. It was of ample size, and performed its work well.

The discharge water was weighed in tanks, and the supply to the condenser was at the same time metered, the tanks serving to calibrate the meter at short intervals. Thermometers were introduced at every important point and frequent readings taken. The indicators were standardized instruments and the motion was conveyed by wire, to avoid all measurable stretch. A counter was secured on the engine frame and driven from the valve-rod. A pencil attached to the valve-rod permitted exact measurements of the motion of the valve to be obtained, and their relation to the motion of the piston noted.

The quality of the steam entering the engine was determined by a calorimeter, and the quality of that entering the low-pressure engine was similarly ascertained. This

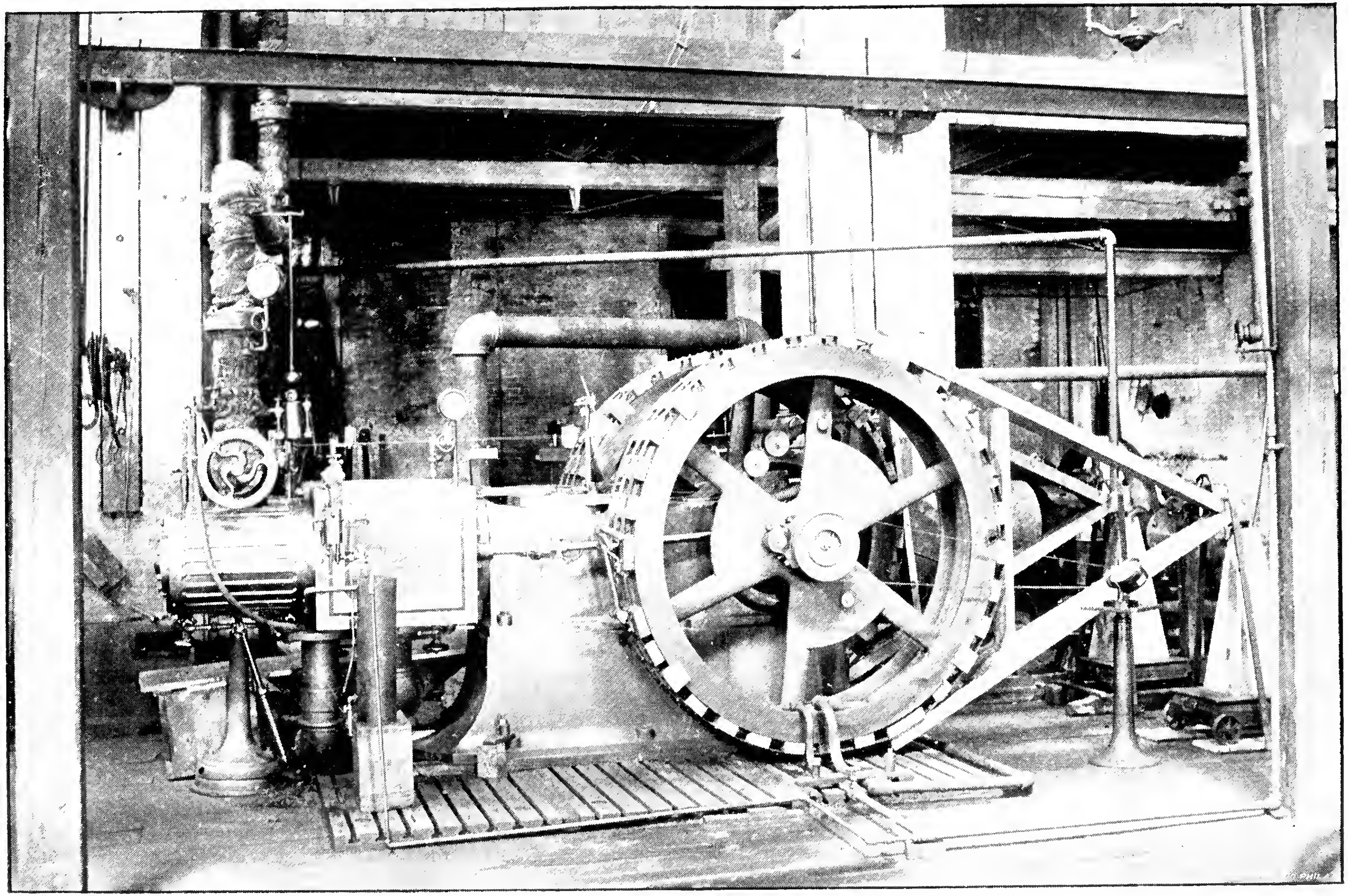


FIG. 1—Engine ready for trial.

was continuous in its operation. The barometric pressure was measured by a mercurial barometer, and that in the condenser was determined in the same manner. In the work of testing, some difficulty was experienced in securing a water supply from the city mains for the condenser, and this restricted the formation of a good vacuum; otherwise the conditions were usually all that could be desired. The computations are given for the best set of data obtained after trial runs had shown what could be accomplished under the circumstances. The work was done at night to insure freedom from interference with the operations of the trial after the conditions of the test were once established. The following are the results:

DATA AND RESULTS.

Time of starting,	6.45 P. M.
Time of stopping,	11.45 P. M.
Duration of trial,	5 hours.
Total number of revolutions (per continuous counter),	60,300
Revolutions per minute,	201
Barometer in inches of mercury,	29·40
Atmospheric pressure,	14·50 pounds.
Boiling temperature at atmospheric pressure,	211°·10
Boiler pressure by gauge,	98·00 pounds.
Boiler pressure, absolute,	112·50 pounds.
Pressure in steam chest, low-pressure cylinder,	34·00 pounds.
Vacuum gauge, inches of mercury,	22·99
Temperature of condensed steam,	130°·8
Temperature of injection water,	47°·9
Temperature of discharge water,	106°·7
Temperature in calorimeter, steam pipe,	212°·8
Quality of steam in steam pipe,	95·50 per cent.
Quality of steam in compression (assumed),	100·00 per cent.
Quality of steam in exhaust,	93·30 per cent.
Total weight of condensed steam,	11594·50 pounds.
Pounds of wet steam per stroke, mean,	·0961484
Pounds of wet steam per stroke, head,	·103593
Pounds of wet steam per stroke, crank,	·088704
Cubic feet of condensing water per minute (by meter),	9·304
Pounds per revolution,	3·033
Pounds per stroke, head,	1·634
Pounds per stroke, crank,	1·399

Length of brake arm, ...	8·07	feet.
Gross weight on brake scale, ...	367·	pounds.
Net weight on brake scale, ...	323·75	pounds.
Available delivered horse-power, ...	99·99	

The brake could not measure all power delivered from the engine, as the engine drove the air-pump arrangement; and this was separately measured by employing an electric motor, when it was found that the power absorbed by the pump was 0·7 horse-power, and, with its accessories when at work, 1·18 horse-power, giving as a total D.H.P 101·17 horse-power, and a machine-efficiency, for the engine itself, of 90·16 per cent. The engine was new and had not been smoothed up by work.

The indicator cards were measured by planimeter. The following are the average mean effective pressures and corresponding power:

	Head.	*Crank.*	*Total.*
M.E.P., high-pressure cylinder, . . .	30·096	26·460	—
M.E.P., low-pressure cylinder, . . .	16·854	13·729	30·579
I.H.P., high-pressure cylinder, . . .	24·132	20·664	44·796
I.H.P., low-pressure cylinder, ...	37·188	30·294	67 482

Total I.H.P., ...	112·28
Total D.H.P., ...	101·17
Efficiency per cent., ...	90·16

Total weight of wet steam, ...	11595·50	pounds.
Weight of wet steam per hour, ...	2319·10	pounds.
Weight of dry steam per hour, ...	2234·72	pounds.

Weight of steam per I.H.P. per hour, ...	*19·903*	pounds.
Weight of steam per D.H.P. per hour, ...	*22·35*	pounds.

The indicator diagrams were found to be sufficiently well taken and finely drawn to permit the application to the case of the methods of Hirn and Dwelshauvers-Dery; the quantity and quality of the steam at every instant in the cylinder being determinable, and the measures of heat transformed and heat transferred without transformation being readily obtained by comparison with the data secured from the observations of boiler performance and steam-supply. Hirn's principle, as here applied, reads thus: "Between any two positions of the piston, the quantity of

heat, which has done external work, and that which is exchanged between the metal and the steam, form a sum equal to the difference between the amount of heat in the steam in those positions; increased (if necessary) by the heat that may have been introduced with new steam, or diminished by that which may have left the cylinder."

The quantity and quality of the steam entering the engine from its steam pipe being measured, and the quality of the mixture discharged from the machine into its condenser being similarly determined, the progressive variations of quality of the charge from the one to the other of its limits of operation within the engine become easy to trace by exact measurement of the pressures and volumes of the steam shown on the diagram. It is known from the data relating to the entering steam what volume and pressure should be exhibited throughout its course through the engine, and the loss of pressure or of volume, at any given instant, as exhibited by the examination of the indicator diagram, gives the measure of loss due to condensation by abstraction of heat from any cause whatever. The condenser supplied data which check any errors in the comparatively difficult measurements of the indicator diagram, and gives comparatively accurate measures, also, of the weight of fluid entering the machine and should give results precisely corresponding with the determinations of weight of feed-water made at the boiler and of quality of the steam entering the steam chest of the engine. The quantity of the fluid leaving the engine at exhaust and entering the condenser is evidently the difference between the quantities of fluid entering the latter as the cooling fluid and that leaving it through the hot-well.

The losses of heat result in the condensation of steam in such quantity as may be required to supply that heat from its stock of "latent" heat or stored energy, in potential form, and correspondingly reduced volume of working fluid. These losses consist of *

---

* *Manual*, chap. v.

(1) Heat transformed into work by thermo-dynamic action.

(2) Heat wasted by the unavoidable thermo-dynamic loss at the end of expansion.

(3) Heat lost by conduction and radiation from the exterior of the cylinders and passages.

(4) Heat wasted by absorption into the metal of the cylinder, and, later, returned to the steam and rejected with it into the condenser without doing useful work.

The compound engine has the advantage of reducing this last waste; while it exaggerates the third of the series. It reduces the last, however, so greatly as more than to compensate the exaggerated loss by external conduction and radiation—provided it is properly proportioned—and permits, thus, the adoption, economically, of a larger ratio of expansion and the securing of higher efficiency than would otherwise be practicable, by the reduction of the second form of waste above enumerated, with consequent increase of the proportion usefully transformed under the first head of our category. In "receiver engines," wastes by conduction and radiation from the intermediate receivers, as well as from the added cylinders, tend to reduce the gain from restriction of internal wastes.* The application of the Hirn system of study to this case involves the determination of the condition of the working fluid as it traverses these receivers and the intermediate steam-passages, as well as at entrance into the high-pressure cylinder and at exit into the condenser. A steam-gauge and a calorimeter provide the means of obtaining the desired data at each of these points. It still remains uncertain, usually, just in what proportion the water carried by the steam is shared between the two ends of the cylinder; and it must generally be assumed that it is divided between them in proportion to steam taken by each.

The data obtained, in the present case, from the trial here referred to, are as follows:

---

* *Manual*, chap. vi.

HIRN'S ANALYSIS—DATA.

High-pressure Cylinder.

	End. Head.	End. Crank.
Cut-off, per cent. of stroke,	26·40	19·83
Release, per cent. of stroke,	75·17	62·91
Compression, per cent. of stroke,	12·56	12·56
Absolute pressure at cut-off,	105·30	104·50
Absolute pressure at release,	56·00	49·00
Absolute pressure at compression,	49·00	46·00
Absolute pressure at admission,	73·00	81·00
Volume in cubic feet, at cut-off,	·40045	·32673
Volume in cubic feet, at release,	·76313	·70351
Volume in cubic feet, at compression,	·27210	·25903
Volume in cubic feet, at admission,	·15716	·14718
External work B.T.U., admission,	4·9000	3·5958
External work B.T.U., expansion,	5·0681	4·8380
External work B.T.U., exhaust	3·4571	2 5497
External work B.T.U., compression,	1·2419	1·2749
External work B.T.U., total,	5 2692	4·6092
Steam from boilers, pounds,	10·3593	8·8704
Steam in clearance, pounds,	2·6906	277·91
Steam, total, pounds,	13·0499	11·6495
Heat in exhaust,	11373·70	9738·80
Heat supplied to engine,	12220·95	10316·00
Sensible heat at admission,	741·45	785·99
Internal heat at admission,	2207·16	2264·20
Sensible heat at cut-off,	3940·42	3510·80
Internal heat at cut-off,	7747·50	6279·00
Sensible heat at release,	3363·00	2901·30
Internal heat at release,	8490·55	6959·30
Cylinder loss during admission,	2991·64	3216·82
Cylinder loss during expansion,	672·44	554·60
Cylinder loss during exhaust,	2535·37	2737·76
Cylinder loss during compression,	536·51	181·83

Low-pressure Cylinder.

	End. Head.	End. Crank.
Cut-off, per cent. of stroke,	36·18	24·48
Release, per cent. of stroke,	88·23	87 72
Compression, per cent. of stroke,	33·82	22·80
Absolute pressure at cut-off,	25·50	26·50
Absolute pressure at release,	12·00	9·70
Absolute pressure at compression,	3·00	3·00
Absolute pressure at admission,	22·00	19·00
Volume in cubic feet at cut-off,	1·2209	·92491

	End. Head.	End. Crank.
Volume in cubic feet at release, ...	2·3974	2·3752
Volume in cubic feet at compression, . .	1·0359	·76953
Volume in cubic feet at admission, . . .	·3142	·3192
Volume in cubic feet of space in pressure plate, ...	·12819	·12819
External work B.T.U., admission, . . .	5·4233	3·5390
External work B.T.U., expansion, . . .	4·1360	4·3582
External work B.T U., exhaust, ...	·4109	·5811
External work B.T.U., compression, . .	1·5339	·9773
Total, ...	7·6146	6·3388
Steam from boiler, pounds, ...	10·3593	8·8704
Steam clearance, pounds, ...	1·7418	1·5387
Steam, total, pounds, ...	12·1011	10·4091
Heat of condensed steam, ...	1023·50	876·40
Condensing water, pounds, ...	108·937	93·279
Heat given to condensing water, ...	9608·30	8227·20
Heat supplied to engine, ...	11373·70	9738·80
Sensible heat at admission, ...	351·51	298·39
Internal heat at admission, ...	1528·00	1362·50
Sensible heat at cut-off, ...	2599·20	2208·30
Internal heat at cut-off, ...	6768·20	5324·50
Sensible heat at release, ...	1980·00	1611·70
Internal heat at release, ...	6783·50	5694·20
Total heat in steam at beginning of compression, ...	935·66	695·07
Heat confined in pressure plate, ...	521·69	465·36
Cylinder loss during admission, ...	3343·48	3512·99
Cylinder loss during expansion, ...	331·39	674·28
Cylinder loss during exhaust, ...	2763·37	2434·66
Cylinder loss during compression, . . .	268·77	402·73

SUMMARY OF RESULTS.

High-pressure Cylinder.

	End. *Head. Per Cent.*	End. *Crank. Per Cent.*
Heat lost by initial condensation, ...	24·48	31·18
Heat restored during expansion, ...	5·50	5·38
Heat rejected during exhaust, ...	20·75	28·11
Heat lost during compression, ...	4·39	1·76
Heat utilized, work (actual efficiency), . . .	4·31	4·47
Thermo-dynamic efficiency, ...	8·77	8·77
Efficiency compared with ideal, ...	49·10	50·90
Quality of steam entering (per calorimeter), .	95·50	95·50
Quality of steam at cut-off (computed), . . .	74·19	67·33

	End.	
	Head. *Per Cent.*	*Crank.* *Per Cent.*
Quality of steam at release (computed), . . .	78·01	71·07
Quality of steam at admission (assumed), . .	100·00	100·00
Quality of steam in exhaust (computed), . .	104·00	104·00

Low-pressure Cylinder.

Heat lost by initial condensation, ...	29·40	36·07
Heat restored during expansion, ...	2·91	6·92
Heat rejected during exhaust, ...	24·30	25·00
Heat lost during compression, ...	2 36	4·13
Heat utilized, work (actual efficiency), ...	6·69	6·51
Thermo-dynamic efficiency, ...	15·66	15 66
Efficiency compared with ideal, ...	42·70	41·56
Quality of steam entering (per calorimeter), .	93·30	93·30
Quality at cut-off (computed).	64·22	50·63
Quality at release (computed), ...	64·76	54·00
Quality at admission (assumed), ...	100·00	100·00
Quality of steam in exhaust (computed), . .	90·12	102·00

Averaging the given values for the head and crank ends for each of the two cylinders, the following values are obtained:

	Cylinders.		
	H.P. *Per Cent.*		*L.P.* *Per Cent.*
Quality of steam entering (per calorimeter), ...	95·50		93·30
Quality of steam at cut-off (computed), .	70·76		57·42
Quality of steam at release (computed), .	74·54		59·38
Quality of steam at admission (assumed),	100·00		100·00
Quality of steam in exhaust (computed),	104 00		96·06
Heat lost by initial condensation, . . .	27·83		32·73
Heat restored during expansion, ...	5·44		4·91
Heat rejected during exhaust, ...	24·43		24·65
Heat lost during compression, ...	3·07		3·24
Heat utilized, work (actual efficiency), .	4·39		6·60
Total, ...		10·99	
Thermo-dynamic efficiency, ...	8·77		15·66
Total, ...		24·43	
Efficiency compared wi h ideal, ...	50·00		42·13
Mean, ...		46·07	

Losses by external radiation could not be measured and set apart; but the engine cylinders were well covered and lagged, and this loss may be estimated as about five per

cent. The form of valve used in this engine is such as, while giving large and free opening of ports, will at the same time vary somewhat the volume of clearances; but not sufficiently, probably, to affect the deductions to be made from the trial and its resultant data. The machine was under loaded, according to the builder's schedule and the condenser could not be supplied with as large a volume of condensing water as was desired by him. These facts must be kept in mind in judging the results as a gauge of the value of the engine as a thermo-dynamic machine. Could water have been obtained in sufficient quantity to produce a vacuum of twenty-six inches, instead of twenty-three, the mean effective pressure of the low-pressure cylinder would have been increased to about 25·5 pounds and nearly six per cent. more power would have been secured, with a gain in economy of about five per cent. Increasing the speed from 201 to its rated value, 250, would also have permitted a gain by reduction of internal wastes of four or five per cent., as computed, from 41·11 per cent. to 36·9, and the steam per hour and per horse-power would, in such case, have become 18·5 pounds, nearly, with the low vacuum, and about 17·75 with the higher vacuum ordinarily obtainable. These figures have been frequently approached by good builders, under favorable conditions.* About twenty pounds is commonly thought good work. The uneven distribution of work between the two ends of the cylinders and the fact that the large cylinder under the circumstances described, performed more than its share of the total work, tell against the machine and reduce the efficiency as found below that which should be attained under more favorable conditions. These facts do not affect the value of the data for present purposes.

Comparing these results with the computations given in the opening portion of this paper, it is seen that the total ratio of expansion was here not far from that found most economical in the earlier investigation, and that the consumption of steam is in close accord with the figures there

---

* *Manual of the Steam Engine*, part i, chap. vi.

obtained and the duty substantially as shown in the accompanying curve, *Fig. 2*. The deduction thus to be drawn is that the constants assumed in the tabulated work are substantially correct for an engine of this class, of good design and construction and operated under ordinarily favorable conditions. The table of engine efficiencies given above may therefore be taken as a probably safe guide in the design of such engines, assuming that correct proportion of volume of cylinders and the best ratios of expansion are adopted for the cases to be met. These proportions are

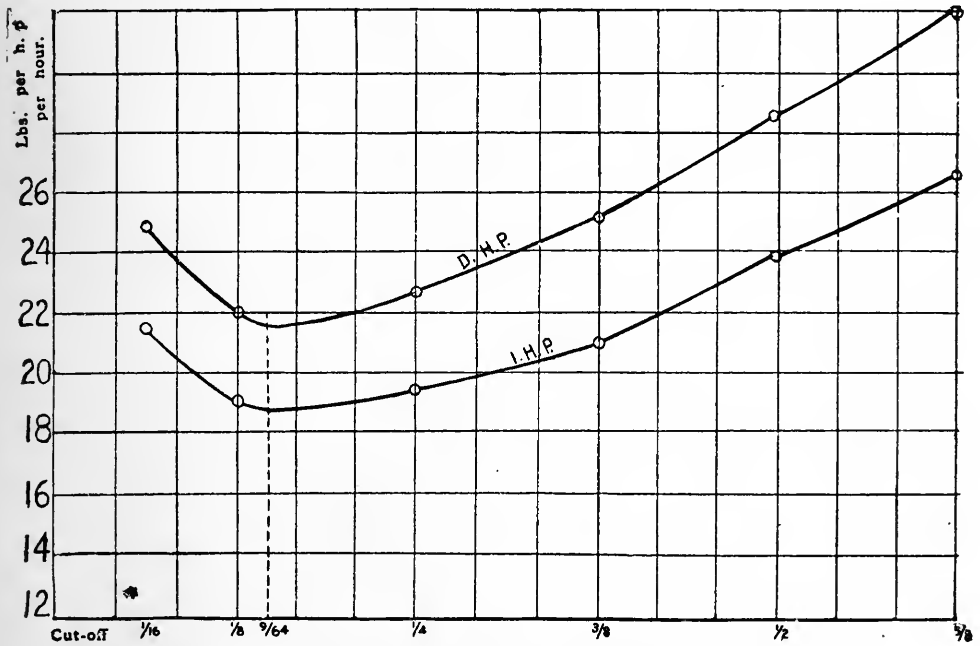


FIG. 2.—Steam consumption. (Compound engine.)

never those found to give minimum cost of steam and fuel, however, and are always such as will exact lower ratios of expansion and smaller ratios of cylinder volumes than those giving maximum fuel economy and highest engine duty. Just to what extent this discrepancy will exist will be determined by costs of engine and of value of fuel and attendance. The best figure is usually two-thirds or three-fourths the value of these ratios, as identified by the processes here described.

---

* *Manual of the Steam Engine*, part i, chap. vii.

The general facts of the case are that the high-speed engine, with its positive valve motion, its single valve system and its usually large clearances, notwithstanding its advantage of high speed of piston and of rotation, gains enough by compounding to barely compensate the losses due those features which, though having special advantage mechanically, are sources of loss thermo-dynamically. It thus happens that the same process of computation of wastes being resorted to, the constants employed may be substantially the same as those obtained by experiment from the older type of four-valve, detachable gear, with its lower speed and smaller clearances, and in some respects, its better steam-distribution. These methods and constants, here found applicable to this engine by test, will presumably apply to other engines of the same class and type under similarly favorable conditions, and may be employed in computation of probable wastes and utilized energy by the designer of such machines, and in the solution of problems involving new conditions, for which results of actual experience are not available. They are to be applied with caution, however, until fully confirmed by repeated and extended investigations, and are to be taken as representative, for the time at least, of limits of expansion for the best makes and best conditions of operation of compounded high-speed engines. In ordinary practice, lower ratios of expansion and higher mean pressures will be found best. Larger engines will give a somewhat lower curve than that shown in *Fig. 2*; smaller or more wasteful engines will give a higher locus for the curve.

THERMO-DYNAMICS OF IDEAL AND REAL ENGINES.

	Cut off.	Initial Pressure, Pounds per Sq. In.	Terminal Pressure Pounds per Sq. In.	Terminal Pressure Pounds per Sq. Ft.	Indicated Power.	Steam per I.H.P. per Hour (Ideal) *W'*.	Internal Waste Coëffic. $\frac{a}{d}\sqrt{\frac{r}{n}}$	Internal Waste, Pounds per I.H.P. and per Hour.	External Waste, Pounds per I.H.P. and per Hour.	Total Waste, Pounds per I.H.P. and per Hour.	Total Consumption Pounds per I.H.P. and per Hour.	Same per D.H.P.
16	1-16	75	3·22	463·7	3·100	15·85	1·234	19·56	3·30	22·86	38·71	45·54
8	1/8	75	7·08	1,020	6·42	15·32	·87287	13·37	1·50	14·93	30·25	35·58
4	1/4	75	15·55	2,239	11·77	16·72	·61720	10·32	·847	11·167	27·887	32·80
2·7	3/8	75	24·29	3,498	14·97	18·48	·50710	9·88	·666	10·546	30·026	35·32
2	1/2	75	34·15	4,918	17·85	21·41	·43650	9·71	·555	10·265	32·51	38·24
1·6	5/8	75	44·00	6,336	19·90	24·76	·3900	9·66	·502	10·162	34·92	41·08
16	1-16	95	4·08	588	4·83	12·74	1·234	15·74	1·663	17·393	30·133	35·45
8	1/8	95	8·97	1,292	9·31	13·21	·87287	11·53	·969	12·499	25·71	30·24
4	1/4	95	19·70	2,837	15·97	15·42	·61720	9·09	·566	9·656	25·076	29·50
2·7	3/8	95	30·77	4,431	20·58	17·72	·50710	8·99	·428	9·418	27·14	31·93
2	1/2	95	43·26	6,229	24·20	20·34	·43650	8·88	·375	9·255	29·595	31·81
1·6	5/8	95	55·72	8,024	26·62	23·11	·3900	9·02	·333	9·353	32·46	38·19
16	1-16	115	4·94	711·8	6·18	11·91	1·234	14·70	1·360	16·060	27·97	32·91
8	1/8	115	10·86	1,564	11·62	12·68	·87287	11·07	·755	11·825	24·55	28·82
4	1/4	115	23·84	3,433	19·68	14·97	·61720	9·24	·415	9·655	26·48	28·97
2·7	3/8	115	37·25	5,364	25·28	17·35	·50710	8·80	·331	9·131	28·836	31·15
2	1/2	115	52·36	7,540	29·64	19·88	·43650	8·68	·276	8·956	30·00	33·92
1·6	5/8	115	67·46	9,714	32·60	22·60	·3900	8·82	·251	9·071	31·67	37·26
16	1-16	135	5·8	835·6	7·534	11·38	1·234	14·05	1·043	15·093	26·473	31·14
8	1/8	135	12·75	1,836	13·91	12·32	·87287	10·75	·504	11·314	23·63	27·80
4	1/4	135	27·99	4,031	23·37	11·67	·61720	9·05	·344	9·394	24·06	28·30
2·7	3/8	135	43·73	6,297	30·00	16·96	·50710	8·60	·263	8·863	25·82	30·37
2	1/2	135	61·47	8,852	35·00	19·54	·43650	8·53	·286	8·756	28·29	33·28
1·6	5/8	135	79·19	11,403	38·50	22·25	·3900	8·68	·208	8·888	31·13	36·62
16	1-16	155	6·66	959·4	8·89	10·98	1·234	13·55	·836	14·336	25·36	28·84
8	1/8	155	14·63	2,106	16·20	12·05	·87287	10·52	·462	10·982	23·03	27·09
4	1/4	155	32·14	4,628	27·00	14·41	·61720	8·89	·274	9·164	23·57	27·73
2·7	3/8	155	50·2	7,223	34·58	16·72	·50710	8·48	·213	8·693	25·41	29·89
2	1/2	155	70·58	10,163	40·50	19·28	·43650	8·41	·182	8·592	27·87	32·74
1·6	5/8	155	90·92	13 092	44·48	21·95	·3900	8·57	·164	8·344	30·68	36·26

ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA.*

BY NIKOLA TESLA.

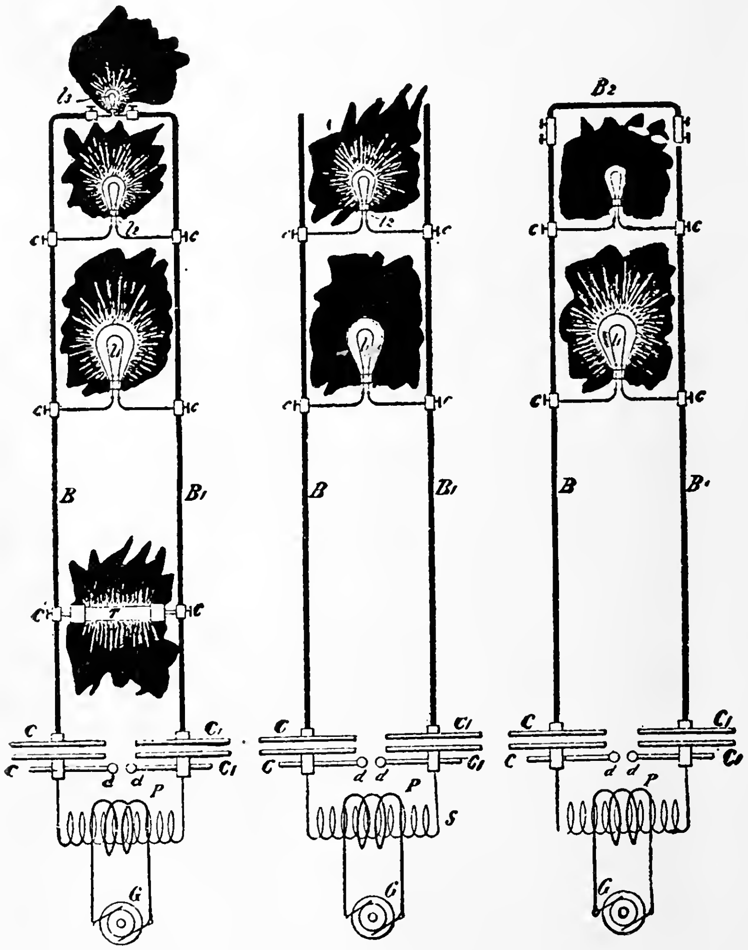
[*Continued from p. 177.*]

Among the various current phenomena observed, perhaps, the most interesting are those of impedance presented by conductors to currents varying at a rapid rate. In my first paper before the American Institute of Electrical Engineers, I described a few striking observations of this kind. Thus I showed that when such currents or sudden discharges are passed through a thick metal bar there may be points at the bar only a few inches apart, which have a sufficient potential difference between them to maintain at bright incandescence an ordinary filament lamp. I also described the curious behavior of rarefied gas surrounding a conductor to such sudden rushes of current. These phenomena have been since more carefully studied and one or two novel experiments of this kind are deemed of sufficient interest to be described here.

With reference to *Fig.* 19*a*, B and B_1 are very stout copper bars connected at their lower ends to plates C and C_1, respectively, of a condenser, the opposite plates of the latter being connected to the terminals of the secondary S, of a high tension transformer, the primary P, of which, is supplied with alternating currents from an ordinary low frequency dynamo G, or distribution circuit. The condenser discharges through an adjustable gap $d\ d$, as usual. By establishing a rapid vibration it was found quite easy to perform the following curious experiment: The bars B and B_1 were joined at the top by a low voltage lamp l_3; a little lower, was placed, by means of clamps $c\ c$, a fifty-volt lamp l_2, and still lower another 100-volt lamp l_1, and finally at a certain

* A lecture delivered before the Franklin Institute, at Philadelphia, February 24, 1893, and before the National Electric Light Association, at St. Louis, March 1, 1893.

distance below the latter lamp, an exhausted tube *T*. By carefully determining the positions of these devices it was found practicable to maintain them all at their proper illuminating power. Yet they were all connected in multiple arc to the two stout copper bars and required widely different pressures. This experiment requires, of course, some time for adjustment, but is quite easily performed.



FIGS. 19*a*, 19*b*, 19*c*.—Impedance phenomena.

In *Figs. 19b* and *19c*, two other experiments are illustrated which, unlike the previous experiment, do not require very careful adjustments. In *Fig. 20b*, two lamps l_1 and l_2, the former a 100-volt and the latter a fifty-volt are placed in certain positions as indicated, the 100-volt lamp being below the fifty-volt lamp. When the arc is playing at *d d*, and the sudden discharges passed through the bars *B B*, the fifty-volt lamp will, as a rule, burn brightly, or at least this

result is easily secured, while the 100-volt lamp will burn very low or remain quite dark, *Fig. 19b.* Now the bars B B, may be joined at the top by a thick cross bar B_2, and it is quite easy to maintain the 100-volt lamp at full candle-power while the fifty-volt lamp remains dark, *Fig. 19c.* These results, as I have previously pointed out, should not be considered to be due exactly to frequency, but rather to the time rate of change which may be great, even with low frequencies. A great many other results of the same kind, equally interesting, especially to those who are only used to manipulate steady currents, may be obtained and they afford precious clues in investigating the nature of electric currents.

In the preceding experiments I have already had occasion to show some light phenomena and it would be now proper to study these in particular; but to make this investigation

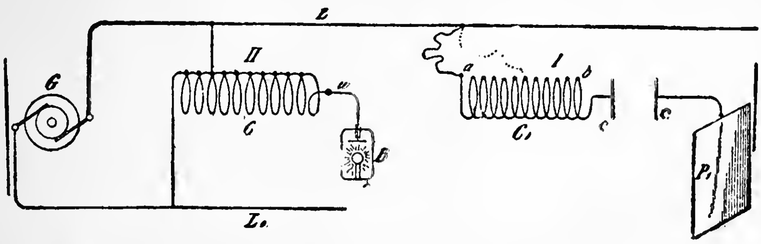


FIG. 20.—Plan followed in observing the effects of resonance.

more complete, I think it necessary first to make a few remarks on the subject of electrical resonance which must always be observed in carrying out these experiments.

On Electrical Resonance.—The effects of resonance are being more and more noted by engineers and are becoming of great importance in the practical operation of apparatus of all kinds with alternating currents. A few general remarks may therefore be made concerning these effects. It is clear that if we succeed in employing the effects of resonance practically in the operation of electric devices the return wire will, as a matter of course, become unnecessary, for the electric vibration may be conveyed with one wire just as well, and sometimes even better, than with two. The question first to answer is, then, Whether pure resonance effects are producible? Theory and experiment both show that such is impossible in nature, for as the oscilla-

tion becomes more and more vigorous the losses in the vibrating bodies and environing media rapidly increase and necessarily check the vibration which otherwise would go on increasing forever. It is a fortunate circumstance that pure resonance is not producible, for if it were there is no telling what dangers might lie in wait for the innocent experimenter. But to a certain degree resonance is producible, the magnitude of the effects being limited by the imperfect conductivity and imperfect elasticity of the mediator, generally stated by frictional losses. The smaller these losses, the more striking are the effects. The same is the case in mechanical vibration. A stout steel bar may be set in vibration by drops of water falling upon it at proper intervals; and with glass, which is more perfectly elastic, the resonance effect is still more remarkable, for a goblet may be burst by singing into it a note of the proper pitch. The electrical resonance is the more perfectly attained, the smaller the resistance or the impedance of the conducting path and the more perfect the dielectric. In a Leyden jar discharging through a short stranded cable of thin wires these requirements are probably best fulfilled, and the resonance effects are therefore very prominent. Such is not the case with dynamo machines, transformers and their circuits, or with commercial apparatus in general in which the presence of iron cores complicates or renders impossible the action. In regard to Leyden jars with which resonance effects are frequently demonstrated, I would say that the effects observed are often *attributed* but are seldom *due* to true resonance, for an error is quite easily made in this respect. This may positively be demonstrated by the following experiment: Take, for instance, two large insulated metallic plates or spheres, which I shall designate *A* and *B*, place them at a certain small distance apart and charge them from a frictional or influence machine to a potential so high that just a slight increase of the difference of potential between them will cause the small air or insulating space to break down. This is easily reached by making a few preliminary trials. If now another plate—fastened on an insulating handle

and connected by a wire to one of the terminals of a high tension secondary of an induction coil, which is maintained in action by an alternator (preferably high frequency)—is approached to one of the charged bodies *A* or *B*, so as to be nearer to either one of them, the discharge will invariably occur between them; at least it will, if the potential of the coil in connection with the plate is sufficiently high. But the explanation of this is to be sought in the fact that the approached plate acts inductively upon the bodies *A* and *B* and causes a spark to pass between them. When this spark occurs, the charges, which were previously imparted to these bodies from the influence machine, must needs be lost, since the bodies are brought in electrical connection through the arc formed. Now this arc is formed whether there be resonance or not. But, even if the spark would not be produced, there is still an alternating E. M. F. set up between the bodies when the plate is brought near one of them; therefore, the approach of the plate, if it *does* not always, actually, will, at any rate, *tend*, to break down the air space by inductive action. Instead of the spheres, or plates, *A* and *B*, we may take the coatings of a Leyden jar with the same result, and in place of the machine, which is preferably a high frequency alternator, because it is more suitable for the experiment and also for the argument, we may take another Leyden jar or battery of jars. When such jars are discharging through a circuit of low resistance the same is traversed by currents of very high frequency. The plate may now be connected to one of the coatings of the second jar, and when it is brought near to the first jar just previously charged to a high potential from an influence machine, the result is the same as before, and the first jar will discharge through a small air space upon the second being caused to discharge. But both jars and their circuits need not be tuned any closer than a basso profundo is to the note produced by a mosquito, as small sparks will be produced through the air space or at least the latter will be considerably more strained owing to the setting up of an alternating E. M. F. by induction, which takes place when one of the jars

begins to discharge. Again another error of a similar nature is quite easily made. If the circuits of the two jars are run parallel and close together, and the experiment has been performed of discharging one by the other, and now a coil of wire be added to one of the circuits whereupon the experiment does not succeed, the conclusion that this is due to the fact that the circuits are now not tuned, would be far from being safe. For the two circuits act as condenser coating and the addition of the coil to one of them is equivalent to bridging them, at the point where the coil is placed, by a small condenser, and the effect of the latter might be to prevent the spark from jumping through the discharge space by diminishing the alternating E. M. F. acting across the same. All these remarks, and many more which might be added but for fear of wandering too far from the subject, are made with the pardonable intention of cautioning the unsuspecting student, who might gain an entirely unwarranted opinion of his skill when seeing every experiment succeed; but they are in no way thrust upon the experienced as novel observations.

In order to make reliable observations of electric resonance effects it is very desirable, if not necessary, to employ an alternator giving currents which rise and fall harmonically, as in working with make- and break-currents the observations are not always trustworthy, since many phenomena, which depend on the rate of change, may be produced with frequencies widely different. Even when making such observations with an alternator one is apt to be mistaken. When a circuit is connected to an alternator there are an infinite number of values for capacity and self-induction which, in conjunction, will satisfy the condition of resonance. So there are in mechanics an infinite number of tuning forks which will respond to a note of a certain pitch, or loaded springs which have a definite period of vibration. But the resonance will be most perfectly attained in that case in which the motion is effected with the greatest freedom. Now in mechanics, considering the vibration in the common medium—that is, air—it is of com-

paratively little importance whether one tuning fork be somewhat larger than another, because the losses in the air are not very considerable. One may, of course, enclose a tuning fork in an exhausted vessel and by thus reducing the air resistance to a minimum obtain better resonant action. Still the difference would not be very great. But it would make a great difference if the tuning fork were immersed in mercury. In the electrical vibration it is of enormous importance to arrange the conditions so that the vibration is effected with the greatest freedom. The magnitude of the resonance effect depends, under otherwise equal conditions, on the quantity of electricity set in motion or on the strength of the current driven through the circuit. But the circuit opposes the passage of the currents by reason of its impedance and therefore, to secure the best action, it is necessary to reduce the impedance to a minimum. It is impossible to overcome it entirely, but merely in part, for ohmic resistance cannot be overcome. But when the frequency of the impulses is very great, the flow of the current is practically determined by self-induction. Now, self-induction can be overcome by combining it with capacity. If the relation between these is such, that at the frequency used they annul each other; that is, have such values as to satisfy the condition of resonance and the greatest quantity of electricity is made to flow through the external circuit, then the best result is obtained. It is simpler and safer to join the condenser in series with the self-induction. It is clear that in such combinations there will be, for a given frequency, and considering only the fundamental vibration, values which will give the best result, with the condenser in shunt to the self-induction coil; of course, more such values than with the condenser in series. But practical conditions determine the selection. In the latter case in performing the experiments one may take a small self-induction and a large capacity or a small capacity and a large self-induction, but the latter is preferable, because it is inconvenient to adjust a large capacity by small steps. By taking a coil with a very large self-induction the critical capacity is reduced to a very small

value, and the capacity of the coil itself may be sufficient. It is easy, especially by observing certain artifices, to wind a coil through which the impedance will be reduced to the value of the ohmic resistance only and for any coil there is, of course, a frequency at which the maximum current will be made to pass through the coil. The observation of the relation between self-induction, capacity and frequency is becoming important in the operation of alternate current apparatus, such as transformers or motors, because by a judicious determination of the elements the employment of an expensive condenser becomes unnecessary. Thus it is possible to pass through the coils of an alternating current motor under the normal working conditions the required current with a low E. M. F. and do away entirely with the false current, and the larger the motor the easier such a plan becomes practicable; but it is necessary for this to employ currents of very high potential or high frequency.

In *Fig. 20I* is shown a plan which has been followed in the study of the resonance effects by means of a high frequency alternator. C is a coil of many turns, which is divided in small separate sections for the purposes of adjustment. The final adjustment was made sometimes with a few thin iron wires (though this is not always advisable) or with a closed secondary. The coil C is connected with one of its ends to the line L from the alternator G and with the other end to one of the plates c of a condenser $c\ c_1$, the plate (c_1) of the latter being connected to a much larger plate P_1. In this manner both capacity and self-induction were adjusted to suit the dynamo frequency.

As regards the rise of potential through resonant action, of course, theoretically, it may amount to anything since it depends on self-induction and resistance and since these may have any value. But in practice one is limited in the selection of these values, and besides these, there are other limiting causes. One may start with (say) 1,000 volts and raise the E. M. F. to fifty times that value, but one cannot start with 100,000 and raise it to ten times that value because of the losses in the media which are great, espe-

cially if the frequency is high. It should be possible to start with, for instance, two volts from a high or low frequency circuit of a dynamo and raise the E. M. F. to many hundred times that value. Thus coils of the proper dimensions might be connected each with only one of its ends to the mains from a machine of low E. M. F., and though the circuit of the machine would not be closed in the ordinary acceptance of the term, yet the machine might be burned out if a proper resonance effect would be obtained. I have not been able to produce, nor have I observed with currents from the dynamo machine, such great rises of potential. It is possible, if not probable, that with currents obtained from apparatus containing iron the disturbing influence of the latter is the cause that these theoretical possibilities cannot be realized. But if such is the case I attribute it solely to the hysteresis and Faucault current losses in the core. Generally it was necessary to transform upward, when the E. M. F. was very low, and usually an ordinary form of induction coil was employed, but sometimes the arrangement illustrated in *Fig. 20II*, has been found to be convenient. In this case a coil C is made in a great many sections, a few of these being used as the primary. In this manner both primary and secondary are adjustable. One end of the coil is connected to the line L_1 from the alternator, and the other line L is connected to the intermediate point of the coil. Such a coil with adjustable primary and secondary will be found also convenient in experiments with the disruptive discharge. When true resonance is obtained the top of the wave must, of course, be on the free end of the coil as, for instance, at the terminal of the phosphorescence bulb B. This is easily recognized by observing the potential of a point on the wire w nearer to the coil.

In connection with resonance effects and the problem of transmission of energy over a single conductor which was previously considered, I would say a few words on a subject which constantly fills my thoughts and which concerns the welfare of all. I mean the transmission of intelligible signals or perhaps even power to any distance without the

use of wires. I am becoming daily more convinced of the practicability of the scheme; and though I know full well that the great majority of scientific men will not believe that such results can be practically and immediately realized yet I think that all consider the developments in recent years by a number of workers to have been such as to encourage thought and experiment in this direction. My conviction has grown so strong that I no longer look upon this plan of energy or intelligence transmission as a mere theoretical possibility, but as a serious problem in electrical engineering, which must some day be carried out. The idea of transmitting intelligence without wires is the natural outcome of the most recent results of electrical investigations. Some enthusiasts have expressed their belief that telephony to any distance by induction through the air is possible. I cannot stretch my imagination so far, but I do firmly believe that it is practicable to disturb by means of powerful machines the electrostatic condition of the earth and thus transmit intelligible signals and perhaps power. In fact what is there against the carrying out of such a scheme? We now know that electric vibration may be transmitted through a single conductor. Why then not try to avail ourselves of the earth for this purpose? We need not be frightened by the idea of distance. To the weary wanderer counting the mile posts the earth may appear very large, but to that happiest of all men the astronomer, who gazes at the heavens and by their standard judges the magnitude of our globe, it appears very small. And so I think it must seem to the electrician, for when he considers the speed with which an electric disturbance is propagated through the earth all his ideas of distance must completely vanish.

A point of great importance would be first to know what is the capacity of the earth? and what charge does it contain if electrified? Though we have no positive evidence of a charged body existing in space without other oppositely electrified bodies being near, there is a fair probably that the earth is such a body, for by whatever process it was separated from other bodies—and this is the accepted view

of its origin—it must have retained a charge, as it occurs in all processes of mechanical separation. If it be a charged body insulated in space, its capacity should be extremely small less than one-thousanth of a farad. But the upper strata of the air are conducting, and so, perhaps, is the medium in free space beyond the atmosphere, and these may contain an opposite charge. Then the capacity might be incomparably greater. In any case it is of the greatest importance to get an idea of what quantity of electricity the earth contains. It is difficult to say whether we shall ever acquire this necessary knowledge, but there is hope that we may, and that is, by means of electrical resonance. If ever we can ascertain at what period the earth's charge, when disturbed, oscillates with respect to an oppositely electrified system or known circuit, we shall know a fact possibly of the greatest importance to the welfare of the human race. I propose to seek for the period by means of an electrical oscillator, or a source of alternating electric current. One of the terminals of the source would be connected to earth, as, for instance, to the city water mains, the other to an insulated body of large surface. It is possible that the outer conducting air strata or free space contains an opposite charge, and that, together with the earth, they form a condenser of very large capacity. In such case the period of vibration may be very low and an alternating dynamo machine might serve for the purpose of the experiment. I would then transform the current to a potential as high as it would be found possible and connect the ends of the high tension secondary to the ground and to the insulated body. By varying the frequency of the currents and carefully observing the potential of the insulated body and watching for the disturbance at various neighboring points of the earth's surface resonance might be detected. Should, as the majority of scientific men in all probability believe, the period be extremely small, then a dynamo machine would not do and a proper electrical oscillator would have to be produced and perhaps it might not be possible to obtain such rapid vibrations. But whether this be possible or not, and whether the earth contains a charge or not, and whatever may be its period of vibration,

it certainly is possible—for of this we have daily evidence—to produce some electrical disturbance sufficiently powerful to be perceptible by suitable instruments at any point of the earth's surface.

Fig. 21.—Energy transmission to any distance without wires.

Assume that a source of alternating currents *S* be connected, as in *Fig. 21*, with one of its terminals to earth (conveniently to the water mains) and with the other to a body of large surface *P*. When the electric oscillation is set up there will be a movement of electricity in and out of *P*, and alternating currents will pass through the earth, converging to, or diverging from the point *C* where the ground connection is made. In this manner neighboring points on the earth's surface within a certain radius will be disturbed. But the disturbance will diminish with the distance, and the distance at which the effect will still be perceptible will depend on the quantity of electricity set in motion. Since the body *P* is insulated, in order to displace a considerable quantity the potential of the source must be excessive, since there would be limitations as to the surface of *P*. The conditions might be adjusted so that the generator or source *S* will set up the same electrical movement as though its circuit were closed. Thus it is certainly practicable to impress an electric vibration at least of a certain low period upon the earth, by means of proper machinery. At what distance such a vibration might be made perceptible can only be conjectured. I have on another occasion considered the question how the earth might behave to electric disturbances. There is no doubt that, since in such an experiment the electrical density at the surface could be but extremely small considering the size of the earth, the air would not act as a very disturbing factor, and there would be not much energy lost through the action of the air which would be the case if the density were great. Theoretically,

then, it could not require a great amount of energy to produce a disturbance perceptible at great distance, or even all over the surface of the globe. Now it is quite certain that at any point within a certain radius of the source S a properly adjusted self-induction and capacity device can be set in action by resonance. But not only can this be done, but another source S_1, *Fig. 21*, similar to S, or any number of such sources can be set to work in synchronism with the latter, and the vibration thus intensified and spread over a large area, or a flow of electricity produced to or from the source S_1 if the same be of opposite phase to the source S. I think that beyond doubt it is possible to operate electrical devices in a city through the ground or pipe system by resonance from an electrical oscillator located at a central point. But the practical solution of this problem would be of incomparably smaller benefit to man than the realization of the scheme of transmitting intelligence or perhaps power to any distance through the earth or environing medium. If this is at all possible, distance does not mean anything. Proper apparatus must first be produced by means of which the problem can be attacked, and I have devoted much thought to this subject. I am firmly convinced that it can be done, and hope that we shall live to see it done.

On the Light Phenomena produced by High Frequency Currents of High Potential and General Remarks Relating to the Subject.—Returning now to the light effects which it has been the chief object to investigate, it is thought proper to divide these effects in four classes:

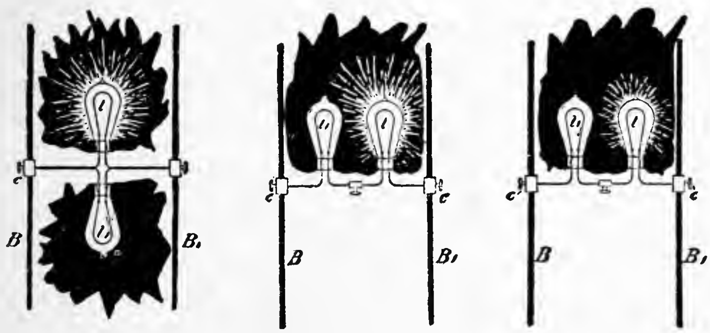
(1) Incandescence of a solid.
(2) Phosphorescence.
(3) Incandescence or phosphorescence of a rarefied gas.
(4) Luminosity produced in a gas at ordinary pressure.

The first question is: How are these luminous effects produced? In order to answer this question as satisfactorily as I am able to do in the light of accepted views and with the experience acquired, and to add some interest to this demonstration, I shall dwell here upon a feature which I consider of great importance, inasmuch as it promises,

besides, to throw a better light upon the nature of most of the phenomena produced by high frequency electric currents. I have on other occasions pointed out the great importance of the presence of the rarefied gas, or atomic medium in general, around the conductor through which alternate currents of high frequency are passed, as regards the heating of the conductor by the currents. My experiments described some time ago have shown that the higher the frequency and potential difference of the currents, the more important becomes the rarefied gas in which the conductor is immersed, as a factor of the heating. The potential difference, however, is, as I then pointed out, a more important element than the frequency. When both of these are sufficiently high, the heating may be almost entirely due to the presence of the rarefied gas. The experiments to follow will show the importance of the rarefied gas, or generally of gas at ordinary or other pressure as regards the incandescence or other luminous effects produced by currents of this kind.

I take two ordinary fifty-volt sixteen candle-power lamps which are in every respect alike, with the exception that one has been opened at the top and the air has filled the bulb, while the other is at the ordinary degree of exhaustion of commercial lamps. When I attach the lamp which is exhausted to the terminal of the secondary of the coil, which I have already used as in experiments illustrated in *Fig. 15a*, for instance, and turn on the current, the filament as you have before seen comes to high incandescence. When I attach the second lamp, which is filled with air, instead of the former, the filament still glows, but much less brightly. This experiment illustrates only in part the truth of the statements before made. The importance of the filament's being immersed in rarefied gas is plainly noticeable but not to such a degree as might be desirable. The reason is that the secondary of this coil is wound for low tension, having only 150 turns, and the potential difference at the terminals of the lamp is therefore small. Were I to take another coil with many more turns in the secondary, the effect would be increased, since it depends partially on the potential differ-

ence, as before remarked. But since the effect likewise depends on the frequency, it may be properly stated that it depends on the time rate of the variations of the potential difference. The greater this variation the more important becomes the gas as an element of heating. I can produce a much greater rate of variation in another way, which, besides, has the advantage of doing away with the objections, which might be made in the experiment just shown, even if both the lamps were connected in series or multiple arc to the coil, namely, that in consequence of the reactions existing between the primary and secondary coil the conclusions are rendered uncertain. This result I secure by charging from an ordinary transformer, which is fed from the alternating current supply station, a battery of condensers,



FIGS. 22*a*, 22*b*, 22*c*.—Showing the effect of the presence of a gaseous medium.

and discharging the latter directly through a circuit of small self-induction, as before illustrated in *Figs. 19a, 19b, 19c.*

In *Figs. 22a, 22b* and *22c*, the heavy copper bars B B_1 are connected to the opposite coatings of a battery of condensers, or generally in such way that the high frequency or sudden discharges are made to traverse them. I connect first an ordinary fifty-volt incandescent lamp to the bars by means of the clamps *c c*. The discharges being passed through the lamp, the filament is rendered incandescent, though the current through it is very small, and would not be nearly sufficient to produce a visible effect under the conditions of ordinary use of the lamp. Instead of this, I now attach to the bars another lamp exactly like the first, but with the seal broken off, the bulb being therefore

filled with air at ordinary pressure. When the discharges are directed through the filament, as before, it does not become incandescent. But the result might still be attributed to one of the many possible reactions. I therefore connect both the lamps in multiple arc, as illustrated in *Fig. 22a.* Passing the discharges through both the lamps, again the filament in the exhausted lamp l glows very brightly while that in the non-exhausted lamp l_1 remains dark, as previously. But it should not be thought that the latter lamp is taking only a small fraction of the energy supplied to both the lamps; on the contrary, it may consume a considerable portion of the energy and it may become even hotter than the one which burns brightly. In this experiment the potential difference at the terminals of the lamps varies in sign theoretically 3,000,000 or 4,000,000 times a second. The ends of the filaments are correspondingly electrified, and the gas in the bulbs is violently agitated and a large portion of the supplied energy is thus converted into heat. In the non-exhausted bulb there being a few million times more gas molecules than in the exhausted one, the bombardment, which is most violent at the ends of the filament, in the neck of the bulb, consumes a large portion of the energy without producing any visible effect. The reason is that, there being many molecules, the bombardment is quantitatively considerable, but the individual impacts are not very violent, as the speeds of the molecules are comparatively small, owing to the small free path. In the exhausted bulb, on the contrary, the speeds are very great and the individual impacts are violent, and therefore better adapted to produce a visible effect. Besides, the convection of heat is greater in the former bulb. In both the bulbs the current traversing the filaments is very small, incomparably smaller than that which they require on an ordinary low frequency circuit. The potential difference, however, at the ends of the filaments is very great and might be possibly 20,000 volts or more, if the filaments were straight and their ends far apart. In the ordinary lamp a spark generally occurs between the ends of the filament or between the platinum wires outside, before such a difference of potential can be reached.

It might be objected in the experiment before shown that the lamps, being in multiple arc, the exhausted lamp might take a much larger current, and that the effect observed might not be exactly attributable to the action of the gas in the bulbs. Such objections will lose much weight if I connect the lamps in series, with the same result. When this is done and the discharges are directed through the filaments it is again noted that the filament in the non-exhausted bulb l remains dark, while that in the exhausted one (l) glows even more intensely than under its normal condition of working, *Fig. 22b.* According to general ideas the current through the filaments should now be the same, were it not modified by the presence of the gas around the filaments.

At this juncture I may point out another interesting feature, which illustrates the effect of the rate of change of potential of the currents. I will leave the two lamps connected in series to the bars B B_1, as in the previous experiment, *Fig. 22b*, but will presently reduce considerably the frequency of the currents, which was excessive in the experiment just before shown. This I may do by inserting a self-induction coil in the path of the discharges, or by augmenting the capacity of the condensers. When I now pass these low frequency discharges through the lamps, the exhausted lamp l again is as bright as before, but it is noted also that the non-exhausted lamp l glows, though not quite as intensely as the other. Reducing the current through the lamps, I may bring the filament in the latter lamp to redness, and, though the filament in the exhausted lamp l is bright, *Fig. 22c*, the degree of its incandescence is much smaller than in *Fig. 22b*, when the currents were of a much higher frequency.

In these experiments the gas acts in two opposite ways in determining the degree of the incandescence of the filaments; that is, by convection and bombardment. The higher the frequency and potential of the currents, the more important becomes the bombardment. The convection, on the contrary, should be the smaller, the higher the frequency. When the currents are steady there is practically no bom-

bardment and convection may therefore with such currents also considerably modify the degree of incandescence and produce results similar to those just before shown. Thus, if two lamps exactly alike, one exhausted and one not exhausted, are connected in multiple arc, or series, to a direct current machine, the filament in the non-exhausted lamp will require a considerably greater current to be rendered incandescent. This result is entirely due to convection and the effect is the more prominent the thinner the filament. Professor Ayrton and Mr. Kilgour some time ago published quantitative results concerning the thermal emissivity by radiation and convection in which the effect of thin wires was clearly shown. This effect may be strikingly illustrated by preparing a number of small short glass tubes, each containing through its axis the thinnest obtainable platinum wire. If these tubes be highly exhausted, a number of them may be connected in multiple arc to a direct current machine and all of the wires may be kept at incandescence with a smaller current than that required to render incandescent a single one of the wires if the tube be not exhausted. Could the tubes be so highly exhausted that convection would be *nil*, then the relative amounts of heat given off by convection and radiation could be determined without the difficulties attending thermal quantitative measurements. If a source of electric impulses of high frequency and very high potential is employed, a still greater number of the tubes may be taken and the wires rendered incandescent by a current not capable of warming perceptibly a wire of the same size immersed in air at ordinary pressure, and conveying the energy to all of them.

I may here describe a result which is still more interesting, and to which I have been led by the observation of these phenomena. I noted that small differences in the density of the air produced a considerable difference in the degree of incandescence of the wires, and I thought that, since in a tube, through which a luminous discharge is passed, the gas is generally not of uniform density, a very thin wire contained in the tube might be rendered incandescent at certain places where the density of the gas was low,

while it would remain dark at the places of greater density, where the convection would be greater and the bombardment less intense. Accordingly a tube *t* was prepared, as illustrated in *Fig. 23*, which contained through the middle a very fine platinum wire *w*. The tube was exhausted to a moderate degree, and it was found that when it was attached to the terminal of a high-frequency coil, the platinum wire *w* would, indeed, become incandescent in patches, as illustrated in *Fig. 23*. Later, a number of these tubes with one

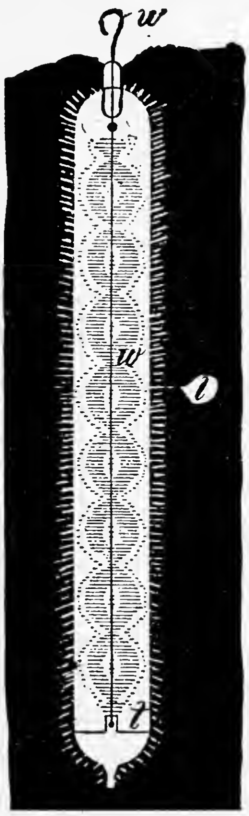


FIG. 23.—Curious incandescence of a wire.

or more wires were prepared, each showing this result. The effect was best noted when the striated discharge occurred in the tube, but was also produced when the striæ were not visible, showing that, even then, the gas in the tube was not of uniform density. The position of the striæ was generally such, that the rarefactions corresponded to the places of incandescence, or greater brightness on the wire *w*. But in a few instances, it was noted, that the bright spots on the wire were covered by the dense parts of the

striated discharge as indicated by l in *Fig. 23*, though the effect was barely perceptible. This was explained in a plausible way by assuming, that the convection was not widely different in the dense and rarefied places, and that the bombardment was greater on the dense places of the striated discharge. It is, in fact, often observed in bulbs that under certain conditions a thin wire is brought to higher incandescence when the air is not too highly rarefied. This is the case when the potential of the coil is not high enough for the vacuum, but the result may be attributed to many different causes. In all cases this curious phenomenon of incandescence disappears when the tube, or rather the wire, acquires throughout a uniform temperature.

Disregarding now the modifying effect of convection, there are then two distinct causes which determine the incandescence of a wire or filament with varying currents; that is, conduction current and bombardment. With steady currents we have to deal only with the former of these two causes, and the heating effect is a minimum, since the resistance is least to steady flow. When the current is a varying one, the resistance is greater, and hence the heating effect is increased. Thus, if the rate of change of the current is very great, the resistance may increase to such an extent that the filament is brought to incandescence with inappreciable currents, and we are able to take a short and thick block of carbon or other material and bring it to bright incandescence with a current incomparably smaller than that required to bring to the same degree of incandescence an ordinary thin lamp filament with a steady or low frequency current. This result is important, and illustrates how rapidly our views on these subjects are changing, and how quickly our field of knowledge is extending. In the art of incandescent lighting, to view this result in one aspect only, it has been commonly considered as an essential requirement for practical success, that the lamp filament should be thin and of high resistance. But now we know that the resistance to the steady flow of the filament does not mean anything; the filament might as well be short and thick; for if it be immersed in rarefied gas it will

become incandescent by the passage of a small current. It all depends on the frequency and potential of the currents. We may conclude from this, that it would be of advantage, so far as the lamp is considered, to employ high frequencies for lighting, as they allow the use of short and thick filaments and smaller currents.

[*To be concluded.*]

CARBORUNDUM: ITS HISTORY, MANUFACTURE AND USES.

By E. G. Acheson.

[*Read at the stated meeting of the Institute, held June 21, 1893.*]

B represents the less attacked mixture of sand, carbon and salt. This mixture surrounds the other shells. An analysis of a sample taken from the top of the mass gave the following composition:

	Per Cent.
(I) Salts soluble in water,	11·19
(II) Carbon, free,	32·96
(III) Ash (insoluble in water),	55·85

The analysis of part I gave the following results:

	Per Cent.
P_2O_5,	0·02
SO_3,	2·43
MgO,	0·04
CaO,	0·19
Al_2O_3,	0·04
Fe_2O_3,	0·71
NaCl,	96·57

Part III had the composition:

	Per Cent.
SiO_2,	94·28
Fe_2O_3,	1·75
Al_2O_3,	4·24
CaO,	0·21
MgO,	0·14

The composition of this—the outer mass—would, however, be a variable quantity, depending upon the original mixture.

While it is not my intention, nor the purpose of this paper, to enter into any exact statements regarding the cost of manufacturing carborundum, I deem the subject one of sufficient interest to justify some few remarks and figures.

The quantity produced at the present time will average 150 pounds per day of twenty-four hours, requiring an expenditure of seventy-eight horse-power for a like period, or 1,872 horse-power hours, amounting to twelve horse-power hours for each pound produced. Improvements now being introduced, relating to the design of the furnace and current regulations, will, it is expected, reduce this expenditure about twenty per cent. or thirty per cent. The location of the works—in the centre of the great coal fields of Western Pennsylvania—permits of obtaining cheap fuel, for the steam plant, and cheap coke for the use of the carborundum furnaces. The value of this location is not, however, of so great significance at the present time, as it will prove to be with largely increased production, for, while with an output of 150 pounds per day, the fuel constitutes but one-third of the total cost of the power, with an output amounting to ten times that amount, or 1,500 pounds, it would be approximately two-thirds of the cost. The present practice entails a loss of a considerable quantity of the coke, sand and salt, used in charging the furnaces; the amounts required for producing one pound of carborundum being, approximately, four pounds of mixture containing 1·82 pounds of sand, 1·46 pounds of coke, and ·72 pound of salt. Much of this waste is due to difficulties encountered in re-using portions of the mixture left from former charges, this applies particularly to that portion designated in the diagram as *W*, and that portion of the mixture *B* immediately surrounding it.

The furnace as now used does not materially differ from the early form as shown in the diagram. The advisability of furnishing a ready escape for the gases produced, together with the necessity of having refractory and electrically non-conducting walls, has resulted in the continued use of fire-brick for its construction. These are knocked down after each run and built up fresh for the succeeding one, it

having been found that repeated use, without re-building, reduced the output, owing to the walls becoming, in a measure, conducting from incrustations forming thereon. Four carbon electrodes are used at each end, their size being 2 inches in diameter by 12 inches in length. These carbons are, as in the furnace shown, adjustable lengthwise, permitting of the tightening up of their contacts with the mixture and core. The dimensions of the furnace are 18 inches in width by 12 inches in depth and 6 feet in length. The core consists of granular carbon, placed in the form of a sheet, having a width of about 10 inches, depth 1 inch, and in length, extending the distance intervening between the electrodes, about 5½ feet.

A furnace of this construction and capacity requires from seven and one-half to eight hours' time to complete the transformation of a portion of the charge into fifty pounds of carborundum, and three of them are operated every twenty-four hours. The labor required for the preparation of the mixture, building and charging the furnace, operating and discharging the same, for twenty-four hours, consists of the services of two men and two boys. This same amount of labor would, however, be able to attend to the production of probably four times the amount now made.

From these figures and data, it will be concluded that the cost of manufacturing carborundum, on a large scale, need not exceed, and possibly not equal, the present cost of mining corundum and preparing it for the market.

Carborundum, when removed from the furnace, is a mass of crystals, of varying sizes, the greater number being of a size sufficiently small to pass through a sieve having 2,500 meshes to the square inch, and too large to pass through one having 40,000 meshes. These crystals cling together in so loose a manner that comparatively little effort is required to separate them. In the factory this separation is accomplished by throwing the crude lump material into an iron pan, and causing two heavy iron wheels to roll over it—water being introduced to facilitate the action—and the mass is stirred up continually during the grinding process.

After removal from the grinding pan, the carborundum is placed in stone tanks, and treated with dilute sulphuric acid, for a period of seven days, the object of this treatment being the removal of all iron, it having been found necessary to remove this impurity before firing in the kiln, during the manufacture of wheels, as a destruction of the crystals would result from its presence.

The intrinsic value of carborundum is a quantity yet to be determined. That it will find varied uses in the arts and manufactures cannot be doubted, its three prominent characteristics—great hardness, infusibility and incombustibility—are sufficient to warrant its extensive introduction into special lines. Perhaps no other use to which it can be put will equal in importance that as an abrasive material, and should it find no other, this alone would be sufficient to class it as one of the most valuable of the materials used by the artisan. The use of emery and corundum in the form of wheels and special shapes, while of comparatively recent introduction, has grown to wonderful proportions. At no period in the world's history has the value of time been more highly appreciated than at the present day. Economy of time, increased output with a given amount of labor, and the resultant cheapening of production and consequent lower selling price of the article produced, are the demands of the times. This is being met by the manufacturer by the introduction of improved machinery and more efficient devices for rapid work and quick production. It is probable that the introduction of no other single tool into our factories, mills and shops, has produced so great a saving in labor as the emery wheel. I have not been able to obtain figures giving even an approximate value for the consumption of emery in the United States, and while I am, therefore, not prepared to say what it would actually amount to, I believe that it is several million dollars annually. These figures will convey some idea of the astonishing consumption of the material, but they will scarcely suggest the much greater amount that is, each year, saved in time and labor by its use. If emery has accomplished so much, "What," you will ask, "is left for carborundum to do?"

The amount it will do and save will depend wholly upon its hardness and fitness as an abrasive, over and above these qualities as manifested in emery. The statement has frequently been made by myself and others, that carborundum was equal in hardness to the diamond, while, perhaps, a greater number of persons—who are apparently in a position to know, have stated quite the contrary—that it is not as hard as the diamond. The final determination of this important question, in a manner satisfactory to all interested parties, remains to be made. My own conclusions were arrived at from what, to me, seemed positive tests, made without prejudice, the material having been used on diamond cutters' laps for the practical cutting and polishing of diamonds. The first test for diamond cutting was made by myself. A disc of iron was mounted in a fast running lathe, and the surface having been charged with fine carborundum crystals, a diamond contained in a ring was pressed against the revolving disc, and in from four to five minutes the facet, which had been presented to the disc, was found to be devoid of lustre, of a milky color and scored with lines. The second test was in a diamond-polishing establishment in New York. Here the proprietor was asked to re-polish the diamond above referred to, using, as the polishing agent, carborundum powder. The gentleman kindly consented to make the experiment, under the following conditions: A new lap, free from all diamond powder, should be used; my material would be tried first, and if successful, no charge would be made for the re-polishing, while if not successful, diamond powder would be substituted, and I should pay him $5 for his trouble. He added that in his opinion the $5 was just as good as earned. The new lap was mounted, and a workman supplied with one-half karat of carborundum powder, with which he was instructed to charge the lap and polish the lustreless facet. The diamond had, in the meantime been removed from its setting and mounted in lead, as is the practice in diamond polishing. Much to the surprise of the workman, the proprietor, and in some measure of myself, an application of the diamond to the lap for a period of twenty minutes removed all lines

from the facet and restored it to its former beauty. Since these first tests, I have, at odd times, spent many hours in watching the operation of diamond polishing with carborundum powder, in three different diamond-polishing establishments in New York City. These various tests served to prove that the hardness of carborundum was sufficient to cut diamond surfaces—removing deep lines from them and producing a fine polish—this work being done, in the opinion of some workmen, in a shorter time than could be performed with diamond powder. They also demonstrated that carborundum was not equal to diamond powder, in the first work of cutting the rough diamond and shaping the facet. Its failure to do this first work has been used, by some diamond cutters and others interested in diamonds and their commercial value, as a conclusive argument that it is not as hard as the diamond. While I do not wish to be understood as denying their statements, I am inclined to accept the proofs I have received with my own eyes, as conclusive evidence, that in the form of a very fine powder it compares favorably, in hardness and cutting qualities, to diamond powder of equal fineness, and to account for its failure when applied to the rougher work, it is necessary to take into consideration the brittleness of the crystals, this brittleness being, apparently, very much greater than in the case of the diamond crystal.

It is probable that methods will be worked out for reducing this brittleness, such for instance, as a process of annealing. This question, as to the exact place of carborundum in the scale of hardness, is, after all, one of scientific rather than commercial importance. Sufficient is now known to rate it very much above the abrasives ordinarily used, and as it is in the steel, iron, glass, porcelain and similar industries that the several million dollars worth of emery is yearly consumed, and not in diamond cutting, the question of first importance is, "Can carborundum be used with greater economy than emery?" To put the question in another form, "How will the cost of a given amount of work performed with carborundum compare with the cost of the same work done with emery?"

We will take a case of brass valve grinding; this being a case, where owing to the metal being comparatively soft, the test will favor the softer abrasive. A number of establishments are now using carborundum powder for this class of work. In one factory they formerly used a fine emery which cost them twenty cents per pound, while the carborundum powder cost them twenty times that amount, or $4.00 per pound. The experience of months has demonstrated to them, that in the hands of a good, careful workman, one-eighth of an ounce is sufficient for one day's work, and that with such a quantity the workman will perform not less than twice the amount of work that he could have done with any amount of emery.

The wages of the workmen are $2.50 per day. We here have, as the result of using one-eighth of an ounce of carborundum, costing six and one-fourth cents, an additional output amounting to the labor of one workman at $2.50, and assuming the emery to cost nothing, we have a value for the carborundum used of $2.43¾, and this without counting the value of the larger production turned out from the same machinery, floor space, etc. It must be admitted that this result is not attainable in all cases, for it is evident that a careless workmen could, and does, very materially reduce this saving by his wasteful use of the carborundum powder. This does not, however, change the relative values of the two abrasives, which we know it is possible to obtain. In glass cutting, tests that have been made, indicate that a given amount of work can be performed in one-fourth the time required when emery is used. Much the same conditions regarding time are found to exist in the case of carborundum on hard steel or chilled iron, and the sum of the results thus far obtained indicate an average saving of labor amounting to at least twenty-five per cent.

The value of the other two characteristics referred to—infusibility and incombustibility—as applied to industrial uses, it is at present impossible to determine. It was these qualities that made carborundum a material equal to and perhaps surpassing all others, from which to construct the

small buttons used in the Tesla lamps, as shown in his lecture before the Franklin Institute last February.

The crystallographic formation of carborundum is a subject that has not received any attention at my hands, nor in the works of the Carborundum Company. I am pleased to be able to state, however, that this subject has received the attention of Professors Frazer and Richards.

The specific gravity of green carborundum crystals was found by Dr. Mulhaeuser to be 3·22.

It will be probably as interesting to you as it was at first disturbing to me, to learn that a compound, responding to the formula SiC, has been produced by another without any known knowledge of my investigations. In the transactions of the Academy of Sciences of France (session of Monday, May 16, 1892), will be found a communication under the title, "Contribution to the History of Carbo-silicious Compounds," by Mr. P. Schützenberger. In his communication, Mr. Schützenberger described at length the manufacture of a new chemical compound of simple formula, the symbol being SiC. Briefly stated, his method was to enclose a mixture of silicon and silica in a bone-black crucible, the latter being securely covered with a lid of like material and embedded in lampblack contained in a larger crucible of graphite. This, again, was embedded in a third crucible, and the resulting nest was placed in a suitable furnace and brought up to, and held at, a high heat for some hours. Upon cooling and opening, the contained silicon was found to have been changed to a green substance and to have gained in weight an amount equal to one-half of its original weight, the silica remaining unchanged. An analysis showed the green material to be carbide of silicon with the formula SiC. No reference was made to the presence of crystals, and as it is probable the silicon used was a powder, the carbide was probably, also, in the same form. The disturbed state of mind—not to specify it more definitely—which I first experienced upon learning of Mr Schützenberger's work, was completely relieved when I found the date of his communication was three months later than the date on which Mr. Nikola Tesla exhibited

a lamp containing carborundum, before the assemble scientific societies of France. The composition of what I had called carborundum was not, however, known at that date. Mr. Tesla could not state what it was, nor did any one else, to my knowledge, know that it was carbide of silicon responding to the formula SiC.

APPENDIX.

REPORT OF AN EXAMINATION OF CRYSTALS FURNISHED BY MR. E. G. ACHESON, PRESIDENT OF THE CARBORUNDUM COMPANY.

The specimens examined were aggregations of crystals, the individual crystals, usually more or less disc shaped, varying in their largest dimensions from a fraction of a millimetre to about three millimetres. The faces were usually smooth with brilliant, adamantine lustre. The images reflected from them in the goniometer were frequently double or multiple, sometimes blurred, and sometimes broadened by diffraction. Occasionally, however, single, somewhat sharply defined, images were obtained. The color of some of the crystals was a yellowish-green; that of others varied from a bluish-green to blue.

The crystals were found to be rhombohedral, their disc shape being due to the predominance of the basal pinacoid. The observed forms consisted of numerous direct and inverse rhombohedra, with the basal pinacoid and, in some crystals, the prism of the first order. The following rhombohedra were observed and determined, viz: $\frac{1}{5}$, $\frac{4}{5}$, $\frac{10}{11}$, 1, $\frac{5}{4}$, $\frac{4}{3}$, $\frac{10}{7}$, 2, $\frac{5}{2}$, 4, $\frac{19}{4}$, 5, 10. No evident marks were discovered to distinguish direct from inverse rhombohedra. In one crystal, the following grouping was observed:

Direct rhombohedra.	*Inverse rhombohedra.*
1	$\frac{10}{11}$
$\frac{10}{7}$	2
$\frac{5}{2}$	5
10	$\frac{19}{4}$
	5

In some crystals, like that just described, the rhombohedral symmetry was evident; in others, the direct and

inverse rhombohedra of the same parameters were found on the same crystal, so as to impart to it an appearance of holohedral hexagonal symmetry. This holohedral habit was observed in bluish-green and blue crystals, while in those yellowish-green crystals, which were examined in the goniometer, the habit was rhombohedral. Further investigation will be needed to decide whether this coincidence is accidental or not.

The value for the length of the vertical axis was calculated from four good measurements made on three different crystals, with the following results:

$$
\begin{aligned}
c = {} & 1{\cdot}2267 \\
& 1{\cdot}2261 \\
& 1{\cdot}2264 \\
& 1.2264
\end{aligned}
$$

giving the mean value, $c = 1{\cdot}2264$.

The following are a few angles between the most frequently occurring forms observed:

	Calculated.	Observed.
$o \wedge \frac{10}{11}$, ...	52° 09′ 42″	52° 07½′ to 52° 14½′
$o \wedge 1$, ...	54° 46′ 22″	54° 43¼′ to 54° 50¼′
$o \wedge \frac{5}{4}$, ...	60° 32′ 15″	60° 32′ to 60° 46½′
$o \wedge \frac{10}{7}$, ...	63° 41′ 49″	63° 41½′ to 63° 43¼
$o \wedge 2$, ...	70° 33′ 12″	70° 31′ to 70° 38′
$o \wedge 5$, ...	74° 13′ 39″	74° 13½′ to 74° 15¾′
$o \wedge 10$, ...	85° 57′ 39″	85° 56¾′ to 86° 02′
$1 \wedge 1$ (terminal), ...	90° 04′ 43″	
$2 \wedge 2$ (terminal), ...	109° 29′ 43″	109° 30½′

It is worthy of notice, in view of the isometric crystallization of the diamond, that the rhombohedron chosen as the unit rhombohedron has almost the shape of the cube, while the rhombohedron 2, a frequently occurring form, in combination with the basal pinacoid has very nearly the shape of the regular octahedron.

No distinct cleavage was observed.

In one instance, a twin was observed, two disc-shaped crystals being so grouped that their basal pinacoids made an angle of 109° 29′ + with each other. This would conform to the law, twinning plane, that of the unit rhombohedron.

A flat crystal examined under the microscope in converging polarized light gave the interference figure of a uniaxial mineral, thus confirming the determination of hexagonal symmetry made by measurements with the goniometer.

B. W. FRAZIER,

Professor of Mineralogy and Metallurgy, Lehigh University.

South Bethlehem, Pa., June 21, 1893.

The specific gravity of several grammes was determined by the specific gravity bottle as 3·123, at 25° C. = 60° F. When it was found that the blue crystals were apparently a di-morphic form of the green ones, a sample of each kind was put into a Sonstadt solution of sp. gr. 3·2, which was diluted down carefully until at a sp. gr. of 3·05, at which point the green crystal had sunk while the blue crystal still floated. It was thus evident that the blue variety has a lower specific gravity than the green.

JOSEPH W. RICHARDS.

ANTI-FRICTION BALL BEARINGS AND THEIR MANUFACTURE.

By GEORGE F. SIMONDS.

[*Read at the stated meeting of the Franklin Institute, held April 19, 1893.*]

JOS. M. WILSON, President, in the chair.

MR. SIMONDS :

It was my privilege to read a paper before the members of this Institute, in June, 1888, on the "Metal Rolling Machine," and I am now pleased to bring to your attention a few facts in reference to what has been the natural outcome of that machine; anti-friction ball bearings and their manufacture.

A casual remark, heard at the Paris Exposition, in 1889, called my attention to the importance and value of ball bearings in removing friction, if they could be brought into practical use, and to make a market for the rolling machine

in the manufacture of balls, the subject was brought under consideration, with results which shall be given you to-night.

The fundamental principle on which balls are now used in bicycles is not correct, and illustrations will be given of a bicycle pedal bearing, showing the present style of ball bearing, the new double-cage ball bearing, and the new single- or bevel-cage ball bearing, also the principle of the double cage bearing as applied to heavy work. It will be observed that in the present style of bearing:

(1) The balls are loose, and must be handled singly.

(2) Each ball is required to sustain both the weight and end thrust.

(3) But two rows of balls can be used, one row at each end of the bearing.

(4) On account of the principle on which it is constructed the balls and bearing surfaces wear away.

(5) There must be a means of adjustment on account of this wear.

In the double-cage bearing these conditions are reversed. The balls are confined in cages, and readily and safely handled; one set of balls carries the weight, while another set takes the end thrust; any required number of balls can be utilized; properly made there is practically no wear, and, as there is no wear of the parts, no adjustment is necessary.

The statement that there is practically no wear to a ball bearing when designed and constructed on the correct principle, will undoubtedly be questioned, but as long use shows no change in the measurement of the size of the balls and bearing surfaces, and as the oil with which they are lubricated is not materially discolored, the claim would seem to be justified.

The bevel-cage bearing was originated to take the place of the present style of bearing for light work only, for utility, and for economy in construction. It is superior to the present style of bearing, in that the balls are carried in cages, and that they run on plane bevel surfaces in place of grooved bevel surfaces. The bevel-cage bearing will come into use where the work is very light, and where the greatest

economy in construction is necessary. The double-cage bearing will be generally adopted in those classes of vehicles and machinery where the best is wanted, and economy in use and permanency is in demand.

In subsequent remarks on the *bearings themselves*, reference is made to the double-cage bearings only, in the *manufacture* of the bearings, to both the double- and single-cage bearings.

The shafting and parts of the machinery in a small manufactory were started on these bearings in August, 1891, and have been in constant use since. Several carriages have been mounted on them, and a brougham so constructed has been on the streets of this city for the past thirty days. A street car constructed with bearings with three-eighths inch balls, after constant use for five months, sixteen hours per day, showed no wear whatever. Balls that were applied between plane surfaces under heavy pressure, measured the same at the end of four years, as when first put at work. Several bicyles, ridden constantly for two seasons, developed marked superiority over the old construction. Many instances can be cited, showing the practicability and value of the bearings.

When the proper principles for the bearings had been discovered, and the designs perfected, but a beginning had been made looking to their general introduction. A ball bearing to be of lasting commercial value must be absolutely accurate and reliable. Perfect spheres were indispensable, and they had never been commercially produced, and the balls and bearing surfaces were required to be of a temper always uniform and reliable, and by no known processes could these results be attained. A small shop was erected in which a force of skilled men have been employed for the past twenty months, and steel balls are now made of absolute sphericity, alike one with another, and with great economy, and a system has been developed for making tempered articles uniform in quality, with a great saving in cost over existing methods, for doing similar work. The accuracy and efficiency of the new system of making spheres will be appreciated when it is stated that balls one-sixth,

one thirty-second, one sixty-fourth of an inch in diameter have been ground from pieces of steel, cylindrical in form, so that they do not vary a ten-thousandth part of an inch from perfect spheres or from each other in size.

As the patents covering these various processes and devices are not yet all issued, detailed descriptions must in some cases be withheld, but enough can be made known to convey a general idea.

The new system for making tempered articles is covered by a series of patents under the following titles:

The metallurgical furnace.

The tempering oven.

The double bath hardening process.

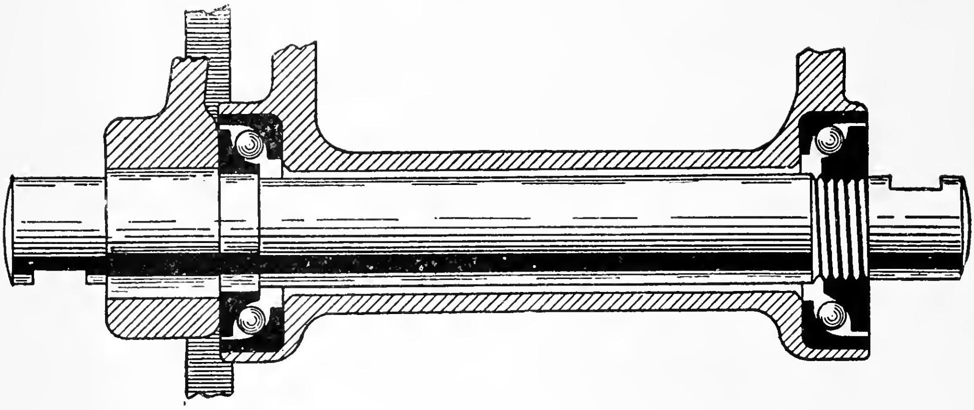
The process for hardening rings and sleeves.

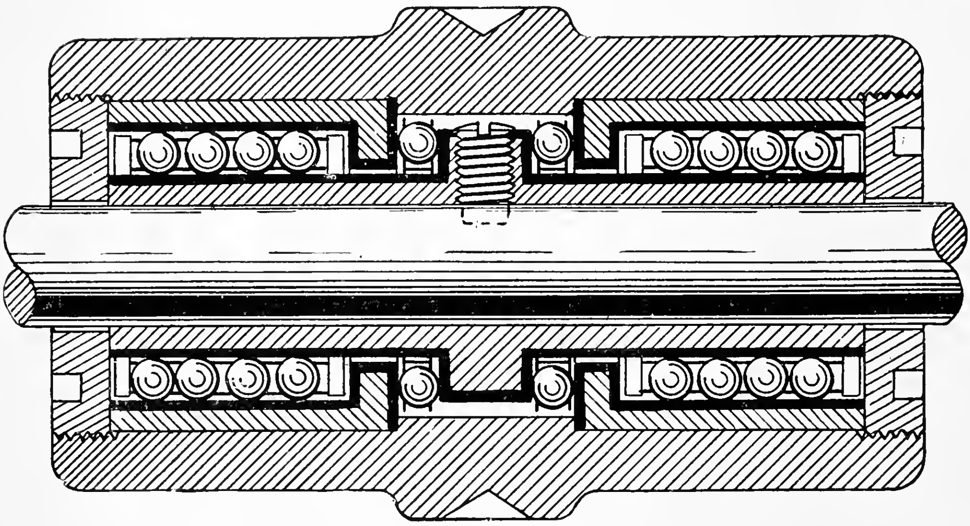
By this system Bessemer or open-hearth steel is used, carrying about ten points of carbon and costing from two cents to three cents per pound, in place of machinery or tool steel, carrying from thirty to 150 points of carbon, and costing from six to sixteen cents per pound.

That those who are not familiar with the nature of steel, and with the terms necessary to be used in this description, it should be stated that steel, no matter by what name it is known, carrying thirty-one hundredths of one per cent. of carbon or less (or thirty points, which descriptive words are now generally used) will not harden, but above that point it will harden, and the higher the percentage of carbon which the steel carries, the harder it will harden. What is known as machinery steel, carries generally less than sixty points; tool steel in general use from sixty to 100 points, and high grades or tool steel from 100 to 150 points.

The carbon in steel, as now in general use for nearly all purposes, extends through its entire structure, and the higher the carbon that may be required in steel for any given article, the more difficult, laborious and expensive it is to work it to its required shape. After an article has been brought to shape, in order to harden it, it is heated to a red heat and suddenly cooled, which makes it harder than, as a rule, it is required or desirable that it should be. It is then again heated and its temper drawn to any required degree

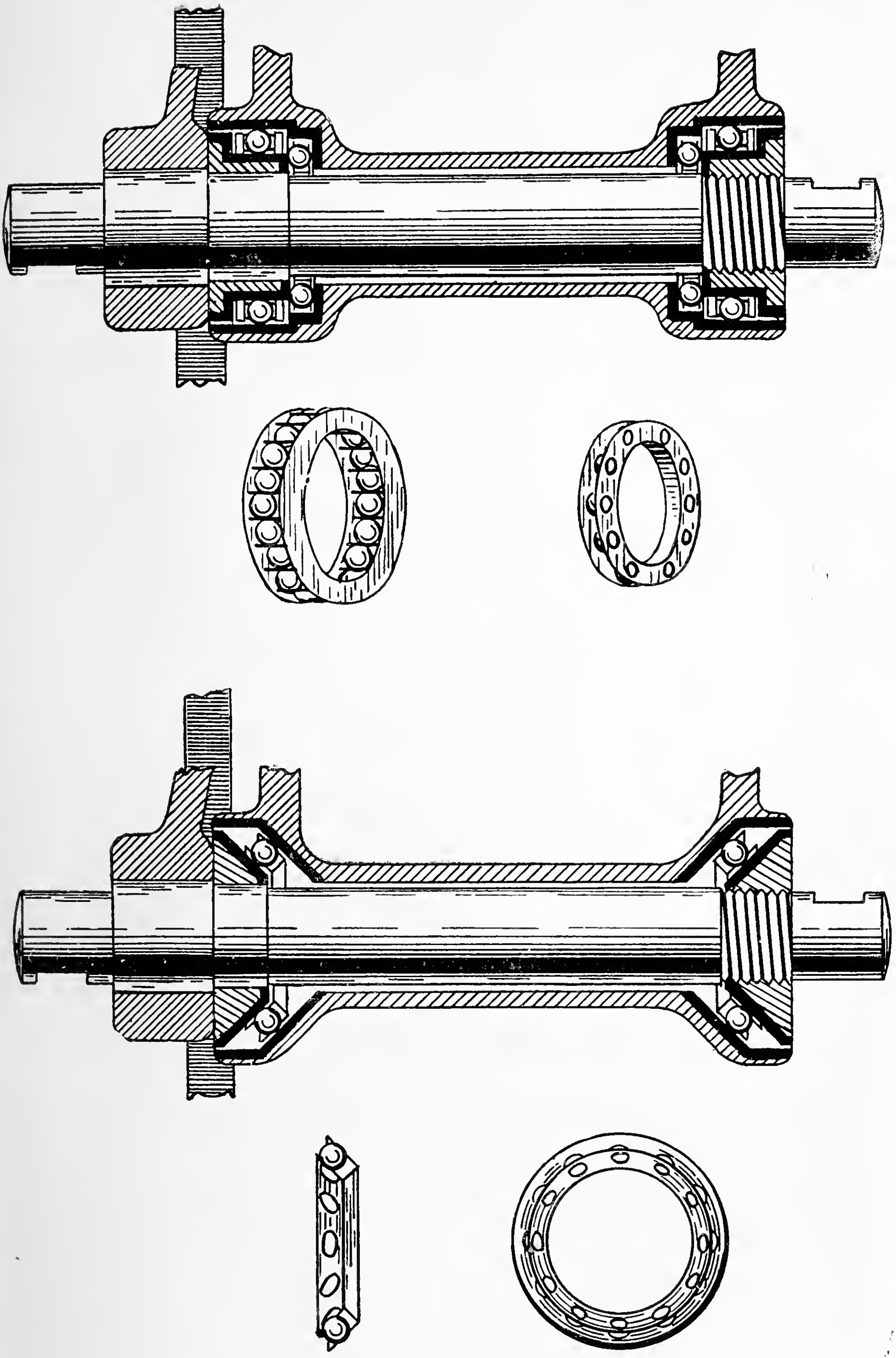
Jour. Frank. Inst., Vol. CXXXVI Oct, 1893.





SIMONDS' IMPROVEMENTS IN

(*Simonds.*)



ANTI-FRICTION BALL BEARINGS.

of softness, which temper is determined, as a rule, by the color the article assumes under the different degrees of heat to which it is subjected. This describes the ordinary process of hardening and tempering. Now, by the hardening process, the quick cooling of a tool made of high carbon steel throughout, causes warping and breaking, and has been a source of untold trouble to workers of steel for all time. It is customary in hardening, when the tool needs to be very hard, to cool the article in water or brine, which cools quickly, this secures the desired hardness, but the sudden cooling sets up unequal strains throughout the article, causing the warping and breaking. When extreme hardness is not required, or when an article cannot safely be dipped in brine, it is cooled in a slow cooling medium, like oil. This hardens to some extent and makes the article tough, and with less liability to fracture.

To largely overcome these difficulties "the double bath hardening process" was devised, by means of which the article is plunged into brine and instantly transferred into oil without coming in contact with the air. By means of this device which I now use for hardening all articles, all the advantages are gotten of both the quick and slow-cooling processes now in use, and with much less liability of fracture, and in many cases it is not necessary to afterwards draw the temper.

There have always been more or less articles made from iron or steel of low carbon and treated to the process known as case hardening. This process, as heretofore practised, has made the surface, as a rule, hard for only a slight depth; to use the expression as generally applied in this connection, "skin deep." Greater depth than this is at times secured, but with no certainty of results. By means of the furnace to which I now refer, the ancient and well-known cementation, case-hardening process is brought under complete control.

All have become familiar with the Harvey process, as applied to armor-plate. Great depth of high carbon is secured by that process in the surface of low-carbon steel, by subjecting the same, while buried in carbonaceous

material, to a high heat, beyond the melting point of cast iron. My furnace was designed and constructed with the view of adopting that process in making the bearing surfaces of these ball bearings, but on testing it, I found that the high heat necessary by the process, raised the grain of the steel, so that it was not adapted for these purposes. The high heat also, as it proved, would destroy the efficiency of my furnace, and I decided to use tool steel for the bearing surfaces and the workmen were instructed to use the furnace for annealing and case-hardening purposes. Later developments, using the ordinary process of case-hardening with the article packed in carbonaceous material in a cast-iron box, demonstrated that the furnace would accomplish, at a low heat, what had before only been possible to do at a high heat. It has taken more than a year of investigation to learn why it accomplishes this result, but this is now known.

By means of this furnace, for the past eighteen months, all the bearing surfaces for these ball bearings have been made from ten carbon Bessemer steel, and also all the reamers, taps, gauges, etc., which have been needed in their construction, as well as a large variety of articles for other purposes.

Having secured, through analysis, the exact result of each days work, it has been demonstrated that formulæ may be established, and by set rules definite and inflexible results will be obtained. The surface of any article can be carburized to any given required depth, and to any high degree of carbon, at a low heat, and in a limited time, without impairing the cutting or wearing qualities of the steel. The furnace is operated at a very moderate expense for fuel, and has needed no repairs in eighteen months of constant use. During that time no article has been cracked or broken through the processes.

By means of the new process for hardening rings and sleeves any number of tubular pieces can be hardened with absolute precision alike one with another. This is especially valuable in the manufacture of the ball bearings, but will, in time, come into general use for all purposes to which it is adapted.

The tempering oven is quite new, and will give a uniform heat for drawing the temper, which, so far as I am aware, is not at present attainable.

These ball bearings have been subjected to an exhaustive test to determine the saving in power and their wearing qualities. This test demonstrated that the friction is less than one-thirtieth of that developed by the best class of ordinary bearings as now in use. The rotating shaft of the testing machine, a machine designed and made especially for the purpose, was two and one-eighth inches in diameter, and the balls as used in the bearings were three-eighths of an inch in diameter. The first series of tests demonstrated that the maximum speed attainable with the best ordinary bearings, under 200 pounds pressure, was 1,000 revolutions per minute, owing to excessive heating of the journals and boxes. A ball bearing mounted on the same shaft at 1,000 revolutions, under a pressure of 2,800 pounds, did not heat at all.

In the second series of tests, ball bearings were introduced in the machine, where the ordinary bearing in the first test had been used. The velocity of the shaft was then increased to 2,600 revolutions per minute, and it was demonstrated that increase of pressure on the bearings did not perceptibly increase the resistance (or friction), and with an increase in the velocity, the resistance was so slight as to be of no material importance.

A test of the resisting power of steel balls was made. Three three-eighths inch balls stood a direct pressure of 175,000 pounds, or 58,000 pounds per ball without injury. The same size balls were rotated between parallel plane surfaces, and under these conditions the balls and the bearing surfaces (the latter Bessemer steel, case hardened) successfully withstood a pressure of 2,500 pounds per ball.

In conclusion, I will say that the work which I lay before you has not extended simply to establishing principles but has been carried into practical use in all its branches. Problems will arise which will need be solved, but they will not be questions of leading importance.

THE CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, September 19, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 19, 1893.

Dr. WM. H. GREENE, President, in the chair.

Mr. J. Benjamin Glavin, 1312 Passyunk Avenue, proposed for membership by Dr. Wahl at the June meeting, was duly elected.

Dr. Wahl also proposed the name of Mr. C. E. Martin, chemist to the house of James Martin & Co., 125 Chestnut Street. At the close of the meeting Mr. Martin was duly elected to membership.

Bills amounting to $93.20, covering items of subscriptions to journals and expenses of addressing and mailing section notices, were approved by vote and ordered to be paid.

The report of the committee appointed to prepare a memorial of the late Conrad J. Semper, was read, accepted and ordered to be spread upon the minutes. (The memorial is printed as an appendix to these minutes.)

Mr. Pemberton read an interesting and carefully prepared paper on "The Determination of Phosphoric Acid by the Titration of the Yellow Precipitate with Standard Alkali." The paper was very favorably commented upon by Dr. Terne and briefly discussed by him and the author.

Professor Smith followed with a paper on "The Atomic Weight of Molybdenum," prepared jointly by himself and Mr. Philip Maas. It was discussed by Mr. R. A. Fisher, the President, and the author. Both papers were referred for publication in the *Journal.*

The meeting then adjourned. WM. C. DAY, *Secretary.*

CONRAD J. SEMPER.

In the death of Conrad J. Semper, which occurred on June 12, 1893, the Chemical Section has suffered the loss of one of its estimable members, who, though his name does not appear as a contributor to the published volumes of its proceedings, was nevertheless a frequent attendant of its meetings and always exhibited a lively interest in its welfare.

Mr. Semper was a son of Gottfried Semper, a distinguished architect, and received his early education at the Polytechnic School at Zürich, completing his studies in chemistry in Berlin, Freiberg, Tübingen and Heidelberg.

In the year 1865, Harrison Brothers & Co., of Philadelphia, being in need of the services of a chemist conversant with a certain branch of manufacture in which they were interested, requested their agents in Germany to aid them in securing a competent person. Through these gentlemen the request was conveyed to Dr. Zürich, who was then Director of the Laboratory of the Prussian Government, and who suggested his assistant, Mr. Semper, for the position. This suggestion resulted in Semper's engagement by the firm.

This engagement proved to be a permanent one, and was fulfilled with such mutual satisfaction that Semper, in due course, became the chemical manager of the house, which post he continued to occupy until his death.

His professional work was naturally confined to the development and improvement of methods and processes connected with the business of manufacturing chemicals and colors, in which the house of Harrison Brothers & Co. occupy the first rank among American manufacturers, and to this congenial work he directed all his energies, and, though no serious contributions to professional literature appear to have come from his pen, the records of the Patent Office bear testimony to his activity and originality in his chosen sphere of work.

His most important technical work appears to have been in connection with the study of the treatment of beauxite for the commercial production of alumina salts especially in the development of the reactions of metallic dioxides (such as those of lead and manganese) upon ferruginous solutions of alumina, for the removal of iron. In this work he was associated with Dr. Constantine Fahlberg, well-known as the discoverer of saccharin.

The house, in whose service his life was spent, bears the following warm testimony to his professional skill: "The late Mr. Semper was without doubt a very able chemist, and, when occasion required, showed great genius. His attention was given generally to our various manufactures, and we regarded him at all times as the fountain source of our chemical knowledge." To this we may add the cordial testimony of his business and professional friends, that his excellent judgment in the planning and erection of buildings and apparatus, and his great experience and eminently practical turn of mind, made him a sound adviser and capable director, whose place it will be difficult to fill.

Personally, Mr. Semper was most amiable in disposition and endeared himself to a wide circle of friends. A widow and three sons survive him.

[SIGNED] DR. BRUNO TERNE,
WM. H. WAHL,
H. PEMBERTON, JR.

ARTESIAN WELLS.

By Oscar C. S. Carter.

Professor of Geology and Mineralogy, Central High School, Philadelphia.

[*Read at the stated meeting of the Chemical Section, held March 21, 1893.*]

[*Continued from p. 239.*]

Deep Artesian Well in the Mica Schist of Philadelphia.—This well was drilled at the Gladstone Hotel, Eleventh and Pine Streets, to obtain water for drinking and household purposes. This well, at the time of writing, December, 1892, is not finished. The present depth of the well is 576 feet; the first forty-four feet passed through was clay and gravel, then the usual mica schist rock was struck. No drillings were preserved, but two specimens of rock broken off by the drill were kept, one at a depth of ninety feet, the other at a depth of 240 feet. The first specimen proved to be hornblende crystallized; the second specimen was mica schist, composed of biotite mica, feldspar and large grains of transparent quartz. I am doubtful about the depth of the first specimen, and think it must have come from a much greater depth than ninety feet, assigned by the driller because no hornblende was seen in any of the pumpings of the well drilled by the Oriental Bath Company, of 1104 Walnut Street. This well was 265 feet in depth, and the drillings were carefully preserved for about every ten feet. The second specimen corresponds with the rock found at nearly the same depth at the Walnut Street well. The first specimen was a mass of a pure hornblende, and may be regarded as an accessory mineral of the mica schist rock, and not as hornblende schist. The well yields 5,100 gallons per hour, and with an improved pump will give over 6,000 gallons per hour. The water rises to within thirty-one feet of the surface, which corresponds closely with the Green Street and Walnut Street wells. On pumping forty-eight hours, or 244,800 gallons, the water falls from the height of thirty-one to fifty-one feet, or a drop of twenty feet in forty-

eight hours, It remains at fifty-one feet from the surface no matter how long it is pumped.

Deep Artesian Wells in the Mica Schist at Jenkintown.—The two wells at Jenkintown were drilled for the purpose of supplying drinking water to the town, and also the surrounding country for a distance of three miles; in this they were eminently successful.

The present depth of the first well is 324 feet; of the second well, 349 feet. They are only eight feet apart. They are both cased for a distance of forty-five feet with iron pipe. The two wells at present are connected. The second well was at first only 270 feet deep, but was afterwards drilled to a depth of 349 feet. On deepening this well they struck at 310 feet a fissure or crevice, which connects the two wells. Before the wells were connected, the water rose to within thirty-eight feet of the surface in the first well, and within sixty feet of the surface in the second. At present they both stand at the same level. The wells yield 9,000 gallons each per hour, and by constant pumping for fifteen hours the fall is 150 feet.

Artesian Well in the Mica Schist of Philadelphia.—This well was drilled at the northwest corner of Twenty-fourth and Green Streets, to obtain water for the manufacture of artificial ice. The well is eight inches in diameter and was drilled to a depth of 300 feet. The well was cased with iron pipe to a depth of thirty feet and afterwards to sixty feet, but it is the intention of the company to case it to a depth of 120 feet.

The water rises to within twenty-six feet of the surface. At the well drilled by the Oriental Bath Company, of 1104 Walnut Street, the water rises to within twenty-eight feet of the surface. The Green Street well yields about 5,160 gallons per hour, while the Walnut Street well yields 6,000 gallons per hour.

The drillings of the Green Street well were not preserved.

The Montgomery County wells are nearly all six inches in diameter and when lined with iron pipe they are five and five-eighths inches in diameter.

The motive-power is a twelve horse-power engine. The beam is fifteen feet in length, the drill bar three inches in diameter. The drill has a drop of eighteen inches.

Artesian Well in the Trias at Norristown, Pa.—This well was drilled on the top of Sandy Hill, a very high hill which overlooks Norristown and the Schuylkill Valley. The drilling was commenced in the bottom of an old dry well, fifty feet in depth, on the property of John T. Dyer.

56—Sandstone,	to 56
6—Dark red shale,	" 62
6—Red shale micaceous,	68
2—Sandstone, light colored transparent quartz, abundance of silvery muscovite,	70
5—Red shale,	75
5—White sandstone muscovite, quartz and pink orthoclase,	80
2—Same,	82
2—Pink sandstone, more pink orthoclase,	84
2—White sandstone, finer grained,	86
5—White sandstone orthoclase, quartz, very little mica,	91
4—Red shale, no mica,	95
5—Red shale, slightly micaceous,	100
2—Red sandstone, fine grained,	102
2—Gray sandstone, little mica,	104
8—Light red sandstone, orthoclase, quartz and muscovite,	112
2—White sandstone, feldspathic,	114
2—Red shale,	116
9—Red sandstone, feldspathic,	125
5—White sandstone, very fine grained, little mica, feldspar missing,	130
5—Dark red sandstone, micaceous,	135
5—Dark red sandstone, slightly micaceous,	140
5—White sandstone like 130, resembles sea sand,	145
5—White sandstone, very fine grained, only little feldspar,	150
10—Pink and white sandstone, orthoclase and muscovite,	160
9—Pink and white sandstone, muscovite and more orthoclase,	169

Very few water crevices were met with, the first crevice was at a depth of seventy-four feet, no water was struck again until a depth of 167 feet was reached. The well was tested when a depth of 121 feet was reached, and was pumped dry in seven minutes, this water mostly came from the first crevice at seventy-four feet. When the depth of 169 feet was reached the well was again tested and yielded

900 gallons per hour, after four hours' steady pumping the water did not lower.

The water rises in the well to within seventy-four feet of the surface. This is rather remarkable when we consider that the hill is a steep one and the well is within a short distance of the slope; many predicted that little water would be found on such a high hill.

Artesian Well in the Silurian Limestone near Lancasterville, Montgomery County, Pa.—This well was drilled on the property of H. F. Hallman. The drilling was commenced in an old well, which was already sixty-four feet in depth.

64 feet	to	64
11—Limestone,	"	75
4—Blue limestone,		79
6—Gray limestone,		85
9—White limestone,		94
2—White limestone, slightly micaceous,		96
2—Gray limestone, slightly micaceous and silicious,		98

Crevices were met with at seventy-nine feet, and four or five between eighty-five and ninety-four feet. The rock was very loose, and the water rises to within sixty-four feet of the surface. The well yields 600 gallons per hour, after five hours' continuous pumping the level does not lower any.

Artesian Well in the Trias Red Shale, Jeffersonville, Montgomery County, Pa.—This well was drilled on the property of of F. A. Poth, and passed through a bed of red shale, forty-six feet in thickness.

10—Clay,	to	10
5—Sandstone,		15
15—Gray sandstone, feldspathic,		30
10—Same,		40
5—Red shale, micaceous,		45
5—Red shale, coarser, more mica,		50
5—Red shale, lighter color, little mica,		55
14—Red shale, very dark in color, much red hematite,		69
6—Red shale, softer micaceous,		75
11—Red shale, dark red, fine grained, micaceous,		86
6½—Sandstone, gray feldspathic, micaceous,		92½

This well was not tested by the drillers, but Mr. Poth put down a deep well steam pump with a capacity of thirty

gallons per minute. It is the opinion of the driller that the well yields twenty gallons per minute. Water was first struck between thirty-five and forty feet, and small crevices were met with below this.

Artesian Well in Trias between Norristown and Jeffersonville.—Well drilled on the property of the West End Land Company, about two miles from the Trenton limestone, which outcrops at Mogee's Station, along the Schuylkill.

10—Yellow sandstone, crumbling, ... to	10
10—Same, ...	20
10—Red shale, micaceous, ...	30
7—Red sandstone, micaceous, ...	37
11—Brown sandstone, micaceous, ...	48
3—Gray sandstone, much gray feldspar, some mica, ...	51
2—Gray sandstone, fine grained, micaceous and feldspathic, .	53
22—Red sandstone, micaceous and feldspathic, ...	75

The well yields 1,500 gallons per hour, and does not lower after four hours' pumping.

This well was about two weeks in drilling.

Artesian Well in the Trias Hickorytown, Montgomery County:

5—Clay, ... to	5
5—Decomposed sandstone, ...	10
30—Light yellow sandstone, ...	40
30—Yellow sandstone feldspathic (orthoclase), ...	70

Below seventy feet is a bed of white sandstone, containing muscovite and orthoclase. Water was first struck at fifty-six feet. The well yields 600 gallons per hour and the water rises to within forty-five feet of the surface.

Artesian Well in the Lowest Trias at Bridgeport, Montgomery County.—This well was drilled in the sandstone not far from the Silurian limestone of the Chester Valley, on the property of Chas. Meyers.

4—Clay, ... to	4
21—Sandstone (decomposed), ...	25
6—Sandstone, coarse grained, light color, trace of mica, . . .	31
9—Red shale, rich in Fe_2O_3, ...	40
12—Sandstone, light color, transparent quartz, slightly micaceous, ...	52
13—Sandstone, fine grained, micaceous, ...	65

The well yields 600 gallons per hour, and after pumping five hours does not lower any.

Artesian Well in the Potsdam Sandstone near Fort Washington.—This well was drilled on the property of J. Conrad, on the Bethlehem Pike, one-half mile from Fort Washington, near the site of Washington's old fort. The rock dipped steeply and it was difficult to keep the well straight.

1½—Soil,	to	1½
13½—Potsdam sandstone, coarse grained, fawn colored,	"	15
15—Potsdam sandstone, fine grained, fawn colored,	"	30
22—Potsdam sandstone, fine, slightly micaceous, darker colored,	"	52
4—Potsdam sandstone, fine, slightly micaceous, fawn colored,	"	56
8—Potsdam sandstone, fine grained, slate colored,	"	64

Water was first struck at depth of fifty-two feet and rose ten feet in the well. The well yields 600 gallons per hour, and on pumping five hours does not lower any.

Artesian Well in the Trias, Sandy Hill School House, Whitpain Township.—

6½—Sand,	to	6½
6½—Sandstone,		13
7—White sandstone, decomposed orthoclase,		20
13—Same, no mica,		33
2—Same,		35
5—Gray sandstone, some clay,		40
10—Red shale,		50
4—White sandstone, highly feldspathic,		54
4—Sandstone and clay, lead colored, micaceous,		58
2—Decomposed shale (clayey),		60

Water first struck at forty feet. The rock changes without any crevices until between fifty-four and sixty feet, when a little more water enters the well. The water rises to within twenty-eight feet of the surface. The well can be pumped dry in thirty minutes on pumping five gallons per minute. It will only yield two gallons per minute without lowering, according to the driller.

Artesian Well at Shady Grove School House, near Skippack Pike, and Morris Road, in the Trias.—

1½—Soil,	to	1½
3½—Decomposed sandstone,	"	5
5—Sandstone, coarse grained, light color (conglomerate),		10
8—Sandstone, finer grained, feldspathic, slightly micaceous,		18

6—Sandstone, coarse, highly feldspathic, much decomposed,		24
6—Same,		30
5—Red clay, derived from feldspar,		35
5—Red shale, slightly micaceous,		40
5—Red clay,		45

This well was about four days in drilling. The rock was very open from fifteen to twenty feet and it was difficult to keep any water in the well and there were small crevices in almost every change of rock, but they did not yield water. Water was first struck at twenty-four feet and rose to within nineteen feet of the surface. The well yields 900 gallons per hour and on pumping three hours and twenty minutes does not lower any.

Artesian Well in the Silurian Limestone, near Williams Station, Plymouth Railroad.—This well was drilled on the property of Thomas Phipps.

11—Soil and clay,	to	11
2—Limestone,		13
7—Limestone, coarse, yellow,		20
10—Same,		30
13—Same,		43

Struck water at sixteen feet. The rock was very loose and kept dropping in the well until harder rock was reached at twenty feet. It was necessary to case with iron pipe to twenty-three. Three crevices were met with from twenty feet to forty-three feet. The water stands at sixteen feet from the surface. The well yields 900 gallons per hour and does not lower on pumping four hours. This limestone is highly magnesian, and on analysis I find it contains a little strontium.

Water Well Drilled in the Trias, at Washington Square School House, Montgomery County.—

3—Soil,	to	3
4—Sandstone,	"	7
7—Fine grained, red shale, micaceous,	"	14
5—Coarse red shale, micaceous,		19
9—Sandstone, very coarse, mica and feldspar,		28
10½—Red clay,		38½

Below thirty-eight and one-half is a bed of red shale. First crevice was met at a depth of twenty-five feet and the

water rose to within fourteen feet of the surface. The well yields 600 gallons per hour and on pumping four hours the water does not lower any. The red clay probably holds the water.

Water Well Drilled in the Trias, at Belfry, Stony Creek Railroad.—This well was drilled at St. John's Lutheran Church.

10—Red shale,	to	10
10—Red shale, deep color, little mica, much Fe_2O_3,	"	20
5—Red shale, lighter color, finer grained, less micaceous,		25
5—Brown shale, hard, fine scales of mica in abundance,		30
2—Sandstone, brownish, gray, micaceous,		32
5—Sandstone, brown,		37

This shallow well yields only thirty gallons per hour; 100 gallons per hour would pump it dry. The water rises to within fifteen feet of the surface. Only one small water crevice was struck and that was at twenty feet. The drillers abandoned this well; the reason it was not finished was because it was impossible to keep the well straight. It started to go crooked at twenty-two feet and continued so all the way down. Every method known to the drillers was tried, but it was impossible to keep it straight. The water was a little hard. No charge was made for drilling.

THE CHLORIDE ELECTRICAL STORAGE BATTERY.

BY HERBERT LLOYD, F.C.S.

[*Read at the meeting of the Electrical Section, Tuesday, Sept. 26, 1893.*]

The electrical accumulator which I will try to describe is known as the chloride cell. It is so called because the plates constituting the element are made up of tablets cast from fused chlorides of lead and zinc, held together by a frame or rim of antimonious lead. When these composite plates are cast, however, they are not capable of use in a storage battery. They do not contain material which is in any sense active material, nor material capable of becoming active in a secondary battery fluid. They are not capable of serving as oxygen plates, as they will not absorb oxygen, nor are they capable of use as hydrogen plates, as not only would their immersion in the dilute sulphuric acid of the storage battery result in contaminating the fluid with chloride of zinc, which would be fatal to its proper action as a storage battery fluid, but the effect of the hydrogen liberated would be to form hydrochloric acid, with the chlorine of the chloride of lead, which hydrochloric acid would further contaminate the fluid and make it inoperative as a storage battery fluid. Moreover, these tablets are non-conductors of electricity. It is plain, therefore, that a plate consisting of tablets of chloride of lead and chloride of zinc is worthless as a storage battery plate, and cannot be used as such. Its chemical composition must first be radically changed to fit it for use either as an oxygen plate or a hydrogen plate.

This chemical change is brought about by means of a bath of chloride of zinc or some equivalent substance, in which the plate of tablets is to be immersed in connection with a slab of metallic zinc. This arrangement is, in fact, a primary battery, in which the zinc acts as the positive element, while the tablets constitute the negative element.

This operation may be performed with current produced

by a dynamo, but it is a very tedious and expensive process as compared with reduction by means of zinc.

The electro-chemical action in this combination results in withdrawing the chloride of zinc from the tablets by simple solution in the bath, and the withdrawal of the chlorine of the chloride of lead from the tablets and fixing it in combination with the zinc with the formation of chloride of zinc. It may, therefore, be said that the chloride of lead tablets constitute material which is destined to become active by electrical disintegration, which is brought about when they are connected with the zinc plates in the bath of chloride of zinc.

When this process of electrical disintegration is complete, and the chloride of zinc is washed out of the plate, a mass of crystallized metallic lead is left, which is suitable for immediate use in a storage battery, without the tedious forming process of Planté and without the application of any active material or material about to become active by the processes of Brush and Faure.

To describe in detail the process used in the manufacture of this plate, as it is carried on commercially, I will begin with metallic lead. The first step in the production of chloride of lead is to bring the lead into such a state of subdivision as to make it readily soluble in nitric acid. The old way of doing this was to pour molten lead into water and so granulate it, but a process which is more satisfactory is to melt the pigs of lead in a suitable furnace, and when the lead is brought to a high state of fusion to convey it through a pipe into closed chamber where it is delivered in a fine stream into a jet of dry steam, the result being that the lead is blown into a moderately fine powder and falls on the floor of the chamber. [Sample shown.]

This powder is then shovelled into earthenware baskets suspended in large tanks of dilute nitric acid. When the lead has gone into solution in the form of nitrate of lead, the clear nitrate of lead solution is run off into precipitating tanks, where, on the addition of hydrochloric acid the chloride of lead is thrown down in a fine white powder, nitric acid being set free. This nitric acid is returned to the dis-

solving pots to be used there again in bringing fresh lead into solution. The precipitated chloride is then washed by decantation and thoroughly dried.

The next step is to mix the chloride of lead so produced with the proper proportion of chloride of zinc, when both are melted together. I will show later on the direct effect produced by the chloride of zinc in the plate.

The fused chlorides are next cast into tablets [samples shown] of any desired size or shape, and with a beveled or V-shaped edge as shown. These tablets are then placed in a second mould, called a framing mould, where they are placed at a fixed distance apart to allow the frame of antimonious lead to be cast around them. In this operation, the result most desirable to obtain is to produce this framing lead in as dense a form as possible, so that unlike the material destined to become active it will not be attacked by the oxidizing current when set up in a cell. The ordinary method of casting storage battery grids is, of course, to pour the molten lead into the mould from an ordinary ladle. We have improved upon this method by forcing the molten alloy around the tablets under heavy pressure, with the result of not only forming a dense metallic frame, but also of making a very perfect contact between the pastille and the frame. The pastille, at the same time, on account of its peculiar form is dove-tailed, as it were, into the frame. This form obviates the trouble so noticeable with the ordinary red lead plate, in which the grid is dove-tailed into the plug; that is, the surface of the plug on each side of the plate is of a larger area than the centre of the plug, so that the tendency is for the plug to split in the centre and fall out on either side.

When the completed plate is taken from the framing mould it is placed in the reducing tank in connection with a plate of zinc, as described in the first instance. This reduction process extends over a period varying from twelve to twenty-four hours, according to circumstances.

When reduction is complete, the plate is thoroughly washed in running water. In order to be sure that the very least trace of chlorine has been removed from the plate, all

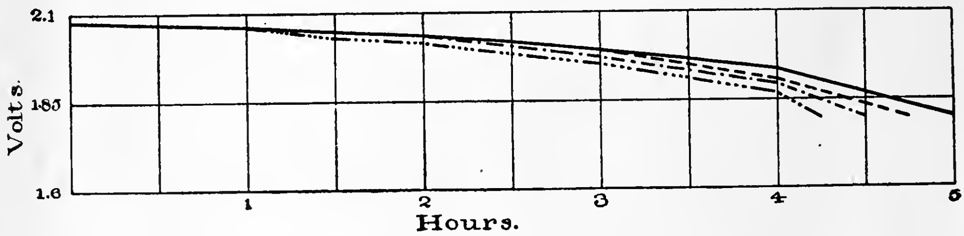
plates are set up as cathodes in a bath of dilute sulphuric acid, plain lead plates being used as permanent anodes in this tank, and a heavy current is passed through the plates for several hours. If the reduction has been incomplete the chlorine will make itself felt in this operation. Excepting through carelessness on the part of the workmen it is practically impossible for the plate to contain any chlorine at this stage.

When the plates are removed from the hydrogen bath they are next set up in forming tanks in connection with the plain lead permanent negatives, and here they are charged continuously for several weeks, or until the crystalline, spongy lead has been completely converted into peroxide of lead. The theoretical amount of current necessary to form a pound of peroxide of lead is about 200 ampère hours, and owing to the beautifully porous structure of the plate this figure holds out very well in practice; the plates will always be found thoroughly peroxidized after they have received a little over the theoretical quantity of current necessary.

The positive plates after formation are then set up with the requisite number of negative plates (the active material of which is in a soft, spongy state as it came from the reducing tank), the lugs or terminals of the plates of each series being burned together with a hydrogen flame, after being insulated in the manner shown in the sample. The cells are then charged and discharged a few times until they give their proper capacity, when they are ready for shipment.

Chloride of zinc is used in this plate for two reasons. In the first place, it is impossible to cast plates of chloride of lead without it, as the casting, on cooling falls to pieces, so the admixture of chloride of zinc is absolutely necessary on that account. In the next place, it will be readily seen that by the use of chloride of zinc it is possible to so control the density of the plate as to produce any porosity that may be desired, and as within certain limits the capacity of a plate is proportional to the porosity, this use of chloride of zinc is of vast importance. The accom-

panying curves show how the capacity of four cells of equal size and weight vary, owing to the different percentage of chloride of zinc which the plates contained when they were cast.



In the manufacture of the ordinary red lead or pasted plate, the density of the material depends mainly upon the energy which the boy uses in pushing the red lead into the grid, and consequently the plates are seldom or ever uniform. In the chloride cell, providing the materials are properly weighed and the mixture thoroughly stirred after fusion, the plates are essentially uniform, as the mixed chlorides become perfectly fluid and every plate cast is exactly like every other plate. It is never necessary to reject any plate for want of capacity.

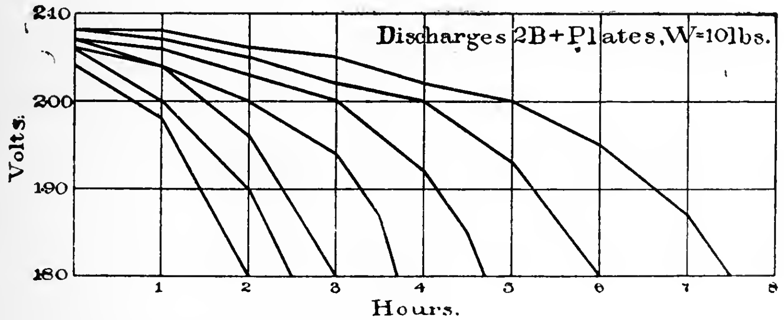
The mixed chlorides on cooling crystallize into a hard, stony substance of a peculiar crystalline nature. After reduction the metallic lead is left in the form of fine acicular crystals, running through the plate perpendicular to its surface, and the elimination of the chlorine and the chloride of zinc provides minute cell spaces around these crystals, so that an immense surface is offered for the absorption of oxygen in the forming process.

Having arrived at the proper amount of chloride of zinc to use, there is no danger of buckling or warping of the plates from undue expansion, as this expansion can be accurately provided for in the tablets.

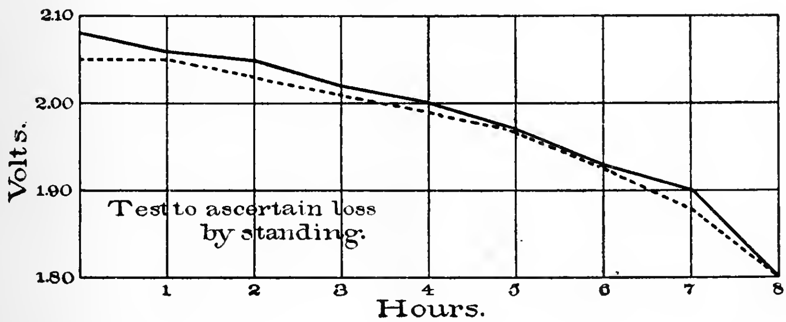
The capacity of cells of this type is from five to six ampère hours per pound of plate. The capacity for weight could be materially increased, but at the loss of durability.

At a discharge rate equal to one-half an ampère for each pound of plate, which is a higher rate than is recommended for any other lead element, this capacity of between five

and six ampère hours per pound can be obtained. At this rate of discharge the efficiency of the cell will be very high, the loss in current being less than ten per cent. and the watt-hour efficiency from seventy-five to eighty-five per cent.



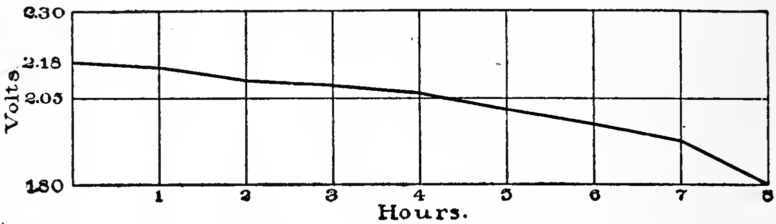
The accompanying set of curves will show the decrease in capacity as the rate is increased. The discharge rate in each of these discharges is above the normal, the lowest discharge being at the rate of three-fourths ampère per pound of plate, and the highest being at the rate of two ampères per pound of plate, or 100 ampères for an ordinary fifty-pound cell, increasing the rate 250 per cent., decreased capacity but thirty-three per cent.



Another set of curves which may be of interest is one showing the effect of allowing a cell to stand charged, the upper curve showing discharge taken immediately after charge, the lower one after the same cell had been allowed to stand charged twenty-four hours. The yield in ampère hours was the same in both cases, but there was a loss in watt hours on standing.

The next curve shows the discharge of a cell at a rate of two-thirds ampère per pound, when it will be seen that

over two-thirds of the capacity was obtained above two volts. At the rate of one-half ampère per pound, over three-fourths of the capacity can be obtained above two volts. This is, in my opinion, a very desirable feature.



While on the subject of capacity, I might mention that a battery of chloride accumulators of about 2,000 ampère hours capacity was installed in the building of the Provident Life and Trust Company, Fourth and Chestnut Streets, in December, 1892. The following letter from the architects, who had the awarding of the contract, speaks for itself:

In regard to the storage battery which you have installed in the Provident building, we would say in the test the battery delivered 1,894 ampère hours, and when the discharge was stopped, as there was still a surplus of five volts, it was evident that the battery was far from being exhausted.

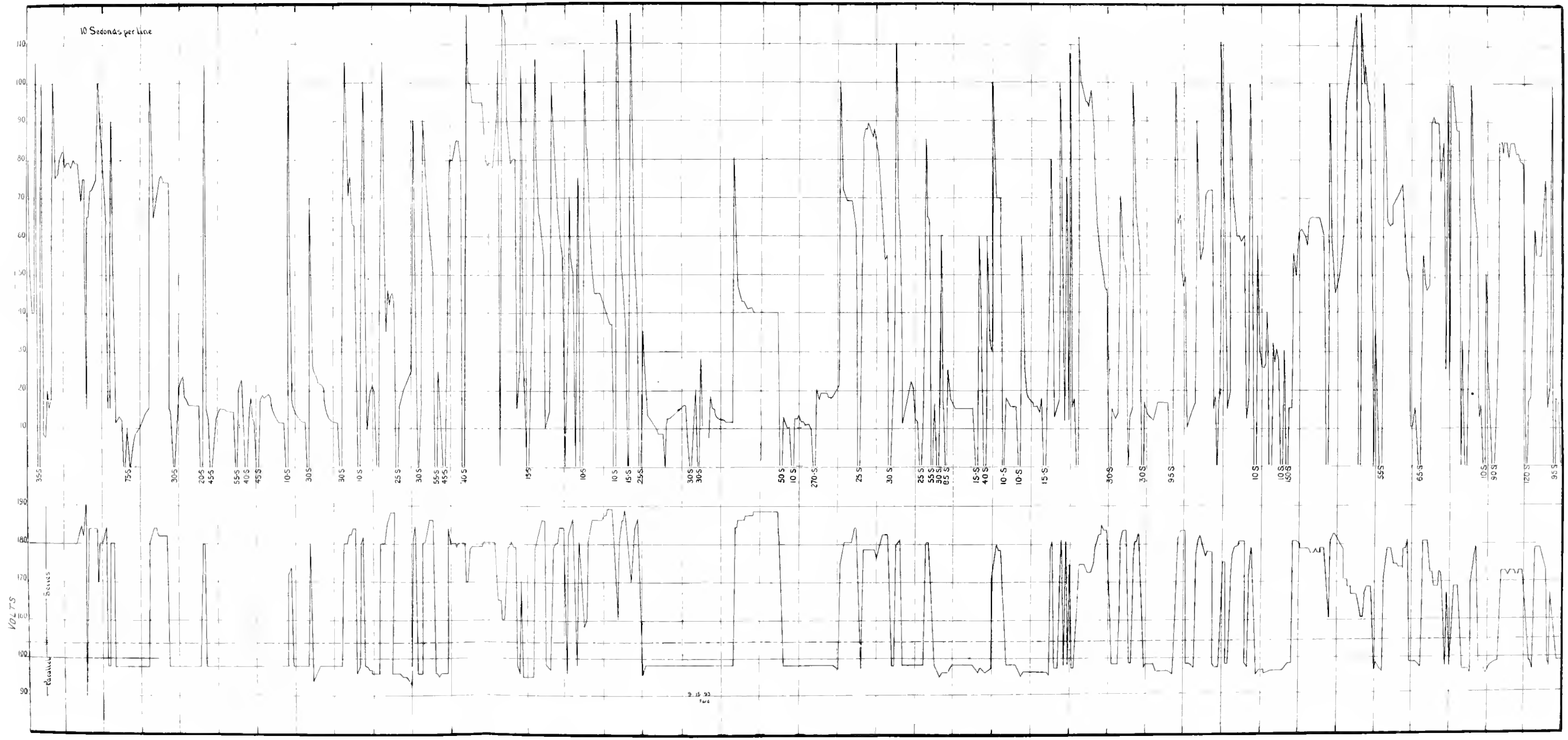
Considering that your guarantee was exceeded by over forty-eight per cent., it certainly speaks very highly for the battery, and is very satisfactory.

Very truly yours,

[SIGNED] FURNESS, EVANS & CO.,
Architects.

The following diagrams, obtained from discharge of the chloride cell on a street car on Lehigh Avenue, in this city, will show the variable loads to which storage batteries are subjected in traction work. In the first, the discharge current ran as high as 200 ampères for a cell weighing less than forty pounds; in the second, over the same road, the current did not pass 100 ampères. One hundred and four cells in series.

The next diagram shows a discharge obtained from a battery of ninety-six cells of the type here shown, on the road of the Metropolitan Company, Washington, D. C. The load in this case was perhaps less than average, the tracks at the same time being in fairly good condition. The trip was about twelve miles, and several five and one-half per cent. grades were encountered, and over fifty curves.



DIAGRAM, SHOWING DISCHARGE OF 96 CHLORIDE CELLS, DURING 12-MILE TRIP, ON CAR OF METROPOLITAN R. R. CO., WASHINGTON, D. C.

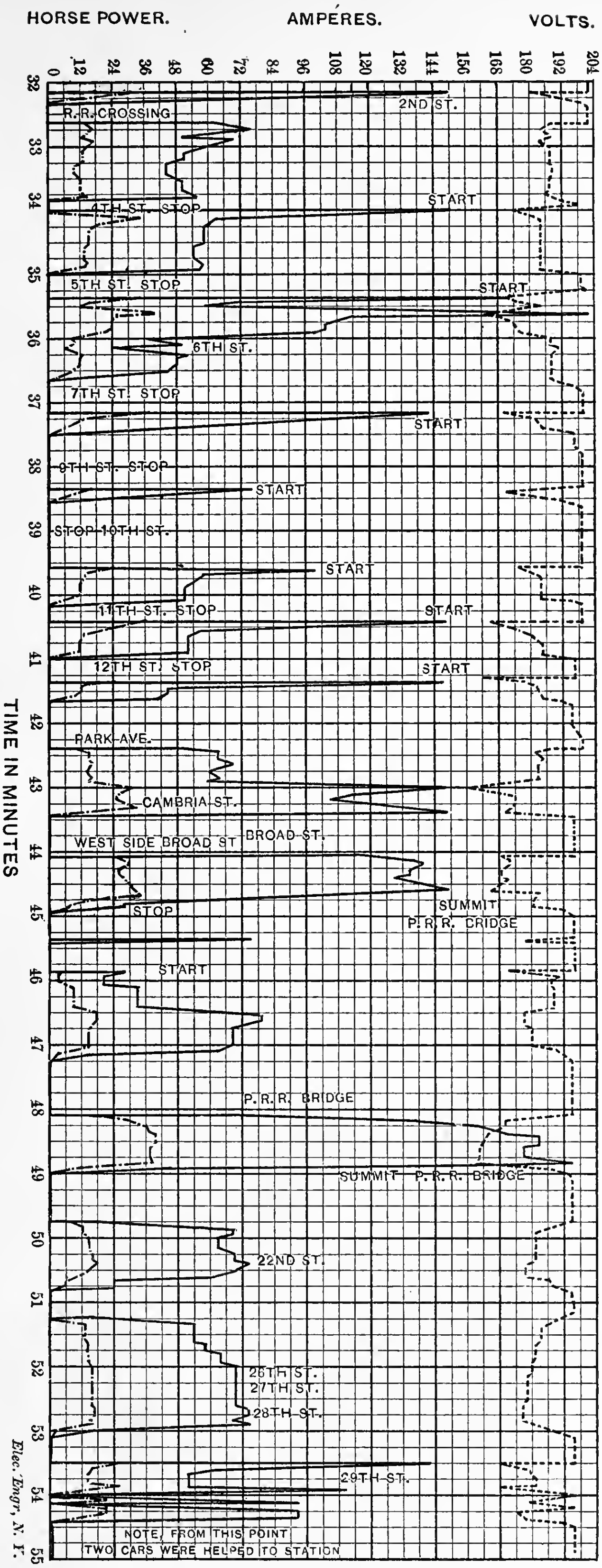


Diagram showing variations in load—Lehigh Avenue Railway, Philadelphia.

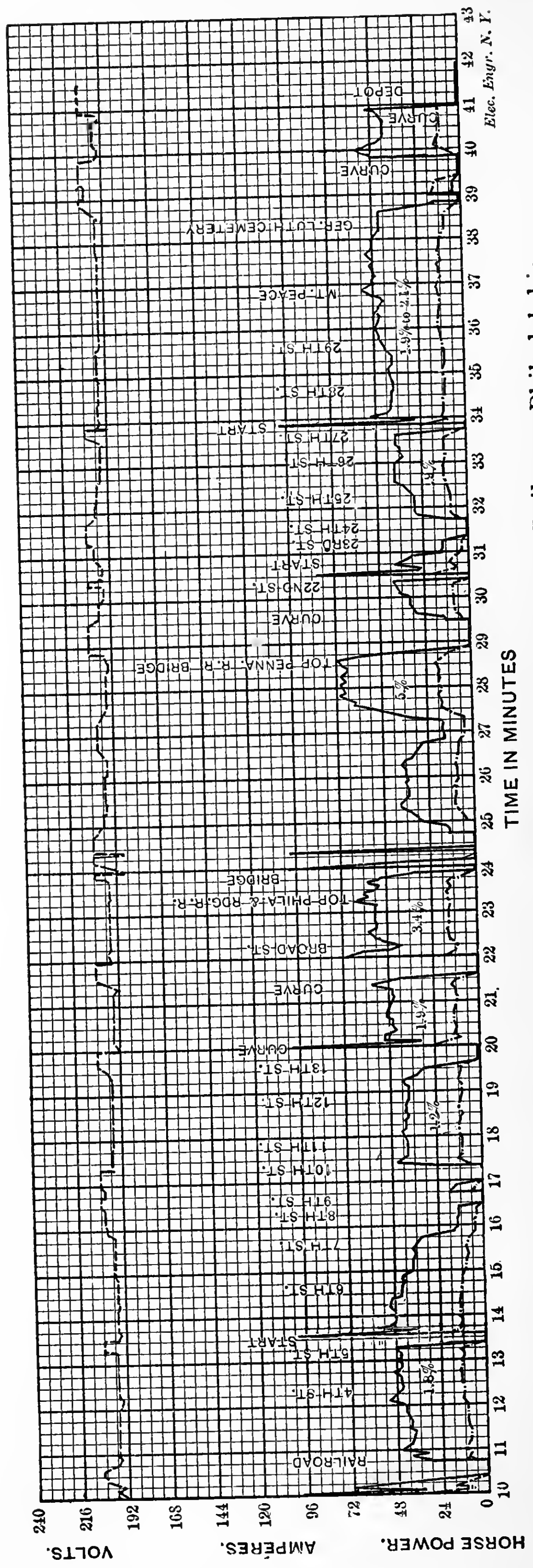


Diagram showing variations in load—Lehigh Avenue Railway, Philadelphia.

A more recent curve, taken after the cells had been in use five months, shows an improvement over this one in voltage.

An examination of the complete element will show the special care that has been given to the insulation of the plates. It is well known that the liability of a storage battery to short-circuit has been one of the main causes of trouble. To overcome this, we envelop the positive plate in a piece of beautifully woven asbestos cloth. Between this positive so protected and the negative plate we place a perforated, grooved board of insulating material, the perforations in this board being made opposite the pieces of active material in both plates, leaving free circulation of the electrolyte between the plates, at the same time keeping the asbestos cloth pressed against the face of the positive plate, causing it to form a tight covering over the face of the active material, and while making the plate absolutely safe from short-circuit, it also adds very wonderfully to the life of the cell, since the peroxide is held in position where it can perform useful work instead of being deposited on the bottom of the cell. The channels in the board provide for the free circulation of the electrolyte, and also allow for the escape of the gases. In traction work this form of insulation is found very beneficial, as the cell is vastly more durable than anything that has been before produced and at the same time there is no unnecessary liquid to be spilled over the car.

It may be of interest to state that the company manufacturing this type of cell in France has supplied batteries for nearly two years to the North Paris Tramway Company, who operate two or three roads with battery cars, about forty cars in all, I believe. I was on these cars about a year ago, and they certainly were doing good work. The cars are about twenty-two feet long, and have seats on the roof, having seating room for fifty-four passengers.

The Paris factory has for some years turned out over five tons of plates a day. They equipped the Popp stations in Paris with these accumulators some three years ago, which have been in constant use ever since. There are twenty-four sub-stations all charged in series, the lighting being done entirely from the batteries, there being two sets

in each station, one being discharged, while the other one is charged. There are in the neighborhood of 100,000 lamps run daily from these cells, the result obtained being very satisfactory, since, in addition to the benefit derived from the batteries as a store, they also act as transformers, as the batteries are charged in a 3,000-volt circuit, each station turning out current to its immediate vicinity at 110 volts. The plates in some of these cells weigh 100 pounds each, the complete cell weighing over a ton, and discharging at a rate of from 1,000 to 2,000 ampères each.

A company has recently been formed in England, for manufacturing these cells, which has just completed works near Manchester, capable of a very large output. That company is controlled by Messrs. Mather & Platt, probably the largest electrical engineers in Great Britain, and the business is to be managed by Dr. Hopkinson. Under such management there can be very little doubt about the success of the business.

The demand for storage battery in Europe is very great. European manufacturing companies, therefore, are not compelled to educate the public into their use.

BOOK NOTICES.

Theory of Structures and Strength of Materials, with Diagrams, Illustrations and Examples. By Henry T. Bovey, M.A., D.C.L., F.R.S.C., Professor of Civil Engineering and Applied Mechanics, M'Gill University, Montreal, etc. New York: John Wiley & Sons. 1893.

Emerson complains of a preacher he once heard, who "had no one word intimating that he had laughed or wept, was married or in love, had been commended, or cheated, or chagrined."

Considering that the Concord Sage is himself rather non-committal respecting these interesting questions connected with his own personality, it would no doubt be unreasonable to expect authors of works upon the theory of structures to inform their readers as to their experience in these respects, and certainly such disclosures by them would be absurdly out of place and undesirable; and yet, as we turn the pages of such volumes as the present one, and contemplate the icy hardness of their style, we are tempted to wonder whether, even in such works, an infusion of somewhat of the author's personality, an occasional intimation of the man behind the printed page, might not render the works even more useful than they are—might not act as mortar to the dry wall, or butter to the dry bread, awakening, intensifying and sustaining the student's interest in the subject, and rendering a part of

him what otherwise may too often be a dry recital of facts and propositions enunciated, and perhaps comprehended, only to be speedily forgotten.

But whether this remark be in order or otherwise, it is not to be taken as referring especially to the work before us, the author of which simply conforms to the established practice of writers of his class. Indeed, his assurance, in the preface, that the examples given are selected for the most part from his own experience, must be taken as a concession to the sentiment here expressed.

The work is a very scholarly, concise and thorough-going exposition of the subjects embraced in its title. Indeed, its scope is made to include matters not usually regarded as pertaining to these subjects, such as dynamics and some of its applications to machinery, the laws of friction as pertaining to journals, pivots, belts, ropes and pulleys, the operation of dynamometers and that of toothed gearing.

Beginning with the simplest possible frame, that of two members, the theory of stresses in more complicated frames is elaborated in Chapter I, largely with the aid of graphic methods, the application of which to the finding of centres of gravity and moments of inertia is also touched upon.

Chapter II deals with the shearing forces and bending moments in solid beams, and somewhat startles the reader at the outset by defining a beam as "a bar of somewhat considerable scantling, supported—," etc.

Chapter III has the rather unfortunate title, "Definitions and General Principles," leading the reader to suppose that the author has carelessly placed here the chapter which should have headed the work; whereas, in fact, the author at this point passes from the action of external to that of internal forces, and proceeds to a discussion of *their* "definitions and general principles."

Under sub-heading (2), "Stresses and Strains," on p. 141, five kinds of stresses are enumerated; but, although deformation is briefly referred to, it is not intimated until in the next paragraph that it is this to which the word "strain" is applied; an application which, although sanctioned by the highest authority and in conformity with present usage, we venture to regard as unfortunate.

This chapter naturally deals with Wöhler's law (referring to it as manifestly incomplete, inasmuch as it fails to take account of the influence due to rapidity of application of load, to the rate of increase of stress and to the duration of individual strains) and with Launhardt's and Weyrauch's efforts to formulate that law; while Tresca's discoveries relating to the flow of solids are briefly described. The remainder of the chapter is devoted to questions of dynamics; such as energy and work, impact and inertia.

Chapter IV continues the discussion of internal stresses and deformations, and extends it into the ticklish domain of the retaining wall. After elaborating the theory to what most engineers will regard as at least a sufficient extent, the author frankly admits that a "a correct theory for the design of retaining walls is as yet wanting," and that "the greatest difficulty in formulating a table of earth-thrusts arises from the fact that there is an infinite variety of earth-work."

Chapter V deals with friction and with its action in structures and in machines. Chapters VI and VII contain a further discussion of the action of beams, including an article by Professor Carus Wilson on the distribution of pressure through the section under the load. Chapter VIII deals with the strength of columns and Chapter IX with torsion. On pp. 585*a* and *b* are large figures showing the distortion of round, square and flat bars under torsional stress; but a hasty review of the text fails to discover any special reference to them. Chapter X discusses the strength of cylindrical and spherical boilers and Chapter XI the design and theory of truss bridges and of riveted joints. Chapter XII is devoted to suspension bridges and Chapter XIII to the theory of arches.

The array of examples, following the several chapters, is exceptionally complete. We notice some, however, which suggest that if the author includes them among those selected from his experience, he must have referred to the experience of the class-room.

The treatment throughout, as is now the case with most works upon these subjects, will be found rather highly mathematical by those engineers who have put some space of time between the present and their college days.

The work abounds in useful tables, among which we may note especially that on pp. 682 to 688, giving the actual weights of modern bridges and compiled from data supplied to the author by many eminent authorities. T.

Encylopédie Scientifique des Aide-Mémoire publiée sous la direction de M. Léauté, Membre de l'Institut. Paris: Gauthier-Villars et fils et G. Masson. Libraires-Editeurs.

Unités et Étalons. Par Ch. Ed. Guillaume. (Broché, 2 fr. 50; cartonné 3 fr.)

Distribution de la Vapeur. Epures de Regulation. Courbes d'Indicateur. Tracé des Diagrammes. Par A. Madamet. (Br., 2 fr. 50; cart., 3 fr.)

Le Lait. Par P. Langlois. (Br., 2 fr. 50; cart., 3 fr.)

The volumes above-named are the latest issued of the interesting and valuable series of the Encyclopédie Scientifique, concerning which we have made more or less extensive references in recent impressions of the *Journal.* These volumes are worthy of quite as much commendation as their predecessors. W.

The Electric Transmission of Intelligence, and other Advanced Principles of Electricity. By Edwin J. Houston, A.M. New York: The W. J. Johnston Company, Limited, 41 Park Row. London: Whittaker & Co. 1893. 230 pp. 89 illustrations. Price, $1.

The third and concluding volume of Professor Houston's *Advanced Primers of Electricity,* is devoted to the telegraph, the telephone, electrolysis, electrometallurgy, the storage battery, electro-therapeutics, electric annunciators and alarms, electric welding, electricity in warfare and several miscellaneous applications of electricity.

The primers on multiple and cable telegraphy and telephony will be particularly appreciated by those who have had no previous knowledge of

electricity, as the author places these subjects in such a light as to make them easily understandable by any reader. The quadruplex and other systems of multiple telegraphy, as well as the principles of cable and time telegraphy need not therefore remain mysteries to the intelligent public in the future as they have in the past.

The other subjects are handled in the admirable and lucid manner that characterizes the writings of the author, whose recent election as President of the American Institute of Electrical Engineers, shows that his electrical attainments are appreciated in the higher circles of the electrical profession.

The extracts from standard authors at the end of each primer is a feature that has been highly praised in the preceding volumes, and has been retained in the present one.

Each primer is, as far as possible, complete in itself and there is no necessary connection between the several volumes of the series, of which the present one is the third and last. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 20, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20, 1893.

JOSEPH M. WILSON, President, in the chair.

Present, 168 members and fifty-three visitors.

Additions to membership since last report, twenty-six.

Mr. W. N. Jennings exhibited an instructive series of photographs taken from a balloon, at altitudes varying from 1,000 to 6,000 feet.

Mr. A. Langstaff Johnston, of Richmond, Va., read a paper descriptive of an automatically operating safety disconnecting device for use upon electric trolley lines. The apparatus is placed in the trolley line at about every 1,000 feet, where the feed wire is tapped in. They are supported from the span wire on the end of a bracket arm. Should the trolley wire be ruptured, springs in the disconnectors on each side of the break, held in extension by the weight and tension of the wire, are released and by their contraction throw certain switches out of contact, thus cutting out the feed taps on each side of the break, which renders the affected section or block dead, but in no manner interferes with the rest of the line. The construction of the apparatus was illustrated with the aid of sectional views and its operation was practically demonstrated upon a short section of trolley line put up for the purpose in the lecture room. With the aid of an electric motor placed in the circuit the sundering of the line wire between two disconnectors was shown to cut out the section between them, while the line wire on both sides was shown to be still "live."

Mr. C. J. Hexamer exhibited a series of lantern slides of buildings and views of the World's Fair, with descriptive remarks on the same.

The meeting then proceeded to the consideration of the amendments to the by-laws of the Institute, which were presented at the stated meeting of June, 1893. (See the *Journal*, June, 1893.)

The President made a brief address explanatory of the action of the Board of Managers in recommending the proposed changes.

The proposed amendments evoked a lengthy and animated discussion, and, on being put to vote, separately, were not approved.

The Secretary presented, on behalf of Professor Rondinella, the following resolution:

That the Board of Managers be requested to consider the subject of the advisability of holding a progress exhibition during the year 1894, and to report thereon at the next stated meeting of the Institute.

The resolution was numerously seconded, and on being put to vote, was adopted.

On Mr. Heyl's motion, the following resolution was likewise adopted:

Resolved, That the Committee on Science and the Arts be authorized to award the Elliott Cresson Medal for such discoveries, inventions or manufactures, as in their opinion shall deserve it, subject to the general regulations on investigations and the following special rules:

(1) Upon the adoption, by the Committee on Science and the Arts, of a report setting forth that an invention or improvement is worthy of an award of the Elliott Cresson Medal, publication shall be made three times in the *Journal of the Franklin Institute*, stating that at the expiration of three months from the date of the first publication, the applicant will be entitled to receive the award of the said medal, unless within that time satisfactory evidence shall have been submitted to the Committee on Science and the Arts of the want of originality of the supposed invention or improvement.

(2) All applications for the Elliott Cresson Medal must be made to the Secretary of the Institute, by whom the applications and accompanying descriptions, drawings, etc., shall be laid before the Committee on Science and the Arts, and by whom all publications ordered by said committee in relation to said medal, shall be made.

On motion of the same member, the meeting voted to repeal the resolution of the Institute of May 17, 1849, defining the manner of awarding the Elliott Cresson Medal.

Adjourned. WM. H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXVI. NOVEMBER, 1893. No. 5

THE STORAGE BATTERY QUESTION.

BY PEDRO G. SALOM.

[*A lecture delivered before the Franklin Institute, January 2, 1893.*]

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

During the past six years I have had the honor, on more than one occasion, to call the attention of the members of the Institute to the subject of storage batteries, or electrical accumulators. On these occasions I have endeavored to give you some idea of the process of manufacturing accumulators and their use in electric lighting or electric traction, a paper on the latter subject having been presented at your June meeting, 1892.

Notwithstanding the serious setbacks the accumulator business has suffered during the last five years, owing to the unfortunate litigation in which it has been involved, the interest in the subject instead of abating is so great to-day that electrical engineers, after condemning for years the use

of storage batteries, are compelled to recognize them, and not only to recognize them, but to adopt them in almost every branch of electrical engineering.

This being the case, it is manifest that a more intimate knowledge of the construction, and operation of a storage battery is desirable, and it will be, therefore, my purpose to-night to call your attention first to the construction of a storage battery, and second to describe briefly the many uses to which a storage battery can be applied. Of course, the subject does not admit of any brilliant or marvellous experiments, such, for example, as Mr. Tesla will show you, but as the storage battery will soon be a factor entering into our daily life, you may be interested in noting these applications, and what is still more valuable, they may have that suggestive influence which will enable some of you to devise new methods and discover new fields of usefulness.

History.—A storage battery is not a new thing. Away back in the early days of this century, a French chemist, named Gautherot, observed that the plates of a voltameter gave a reverse current. A voltameter is an instrument for measuring the galvanic current by means of the chemical action produced, and Gautherot observed that after a galvanic current had been passing through the plates of a voltameter for some time, and was then discontinued, that if he connected the terminals of the voltameter a current was obtained in the reverse direction, and this is the germ of the secondary battery. If, for example, a current of electricity is passed between two lead plates and indeed between any two plates, and then discontinued from the source of the current and their terminals again connected through a voltameter, you will observe a deflection. It was first thought that this secondary current was due to electricity actually charged on the plates in a manner similar to the alleged charge on a condenser, but it was soon discovered that it was due to the substances (gases or oxides as the case might be) derived from the original chemical decomposition.

From 1801 to 1859, the subject was studied by the most eminent chemists and physicists of their time, viz: Ritter, Grove, Oersted, Faraday, Becquerel, and many others.

In 1859, Gaston Planté, who made the most exhaustive researches in secondary batteries, constructed a secondary pile which is really the parent of all modern accumulators. A number of attempts have been made since that time to store the electrical energy of a dynamo, the most notable of which are those of Messrs. Thomson and Houston, in 1879, who patented and afterwards exhibited in this hall a gravity form of the Daniell cell, in which the zinc was reduced from its solution and the copper re-dissolved by the action of charging the cell from a dynamo or other source of electricity. During the last ten years, Chas. F. Brush, of electric light fame, to whom has finally been awarded (in the highest Court of Appeal) the priority of invention of the modern type of accumulator, M. Faure and a host of minor inventors have occupied the field with their respective inventions.

The Planté Battery.—The original Planté battery consisted of plates of lead on which the active material had been produced by electrical disintegration; that is to say, from the oxidizing action of the current alternately on each plate until a portion of the lead plate had been destroyed as lead, or in popular language, had become rusted. The formation of a Planté battery was a very tedious operation, often requiring months before it had been carried sufficiently far to enable the operator to get any useful return from a given charge. The reason for this is clear, from the fact that on charging two lead plates for the first time the oxygen liberated at the positive pole makes a thin film of peroxide of lead, but peroxide is a conductor, and then as the gas is liberated from the surface of the plate the peroxide when once formed really protects the body of the plate from further oxidation during that particular charge. If now we reverse the current and pass it through long enough to reduce all the peroxide to spongy lead, which is exceedingly porous through the loss of oxygen, the spongy mass allows of a freer circulation of the electrolyte, and new surfaces are exposed on an additional reversal whereby more peroxide of lead is formed. It is manifest that if this operation were to be continued long enough, the lead plates would be entirely

converted into peroxide of lead, or spongy lead, and the maximum efficiency and minimum of weight of material would be obtained. But right here is the main difficulty with the Planté battery. As it approaches a useful stage in formation from the amount of active material produced compared with the total weight of the plate, its life is suddenly cut off by reason of there being no longer a sufficient amount of metallic conductor for the current to properly distribute itself with respect to the electrolytic reactions that must take place in recharging. For you must understand that when a battery has been discharged, the peroxide of lead has been converted into sulphate of lead, which is a non-conductor, and the consequence of any attempt to force the current through such a substance will be to detach it from its metallic backing and render it useless, for the active material must be in electrical and mechanical contact with the conducting support in order to be available. If the current does not pass through the active matter to the electrolyte, the active matter is not oxidized or reduced, as the action of the electrolytic gases only takes place at the point of contact. Nascent oxygen and hydrogen are necessary for oxidation and reduction. As the plates are gradually peroxidized in formation the metallic portion which acts as the conductor continues to diminish, the internal resistance to increase until the battery will positively refuse to work, or, what is equivalent to the same thing, the current is all used up in the electrolysis of the electrolyte without accomplishing any useful result. This, then, as I have said, is the radical defect of the Planté battery, and even though it had no others would render its commercial use impossible. If the Planté principle were true, it would only be necessary to have a mass of spongy lead and a plate of peroxide and we would have an ideal battery because this is the logical result to be aimed at. But, unfortunately, for the reason I have explained in regard to the sulphating, it is impossible to accomplish.

We are, therefore, compelled to accept one of two alternatives, either to make a thick plate with low efficiency per pound and comparatively long life, or a thin plate with high

efficiency, but short life. Is there not a central point between the two which we might choose combining the two desirable features—long life with high efficiency? Most assuredly, but before this point is reached the other disadvantages of the Planté system make their presence felt, and a careful study of the problem must convince any intelligent electrical engineer that there can be no future for the Planté battery in competition with the Brush-Faure type.

There have been many forms of the Planté battery, and among the best of these was that adopted by the Brush Company, many years ago, and which was afterwards used, I believe, to light a train on the Pennsylvania Railroad. It consisted of a heavy plate of lead with laminations or leaves extending vertically at right angles to the plane of the plate. These batteries, I understand, worked fairly well, but their ampère hour capacity per pound of battery was so small that in order to accomplish a comparatively small result, for example, operating a few sixteen candle-power lamps, an enormous weight of battery was required, and the expense and trouble in hauling such a weight for so insignificant a return, together with other difficulties, led to its abandonment by the Pennsylvania Railroad after a fair and impartial trial.

The Brush-Faure Battery.—We come now to the consideration of the Brush-Faure type of battery, the type that has finally replaced all others, and notwithstanding the fact that the subject has been studied during the last ten years by some of the brightest chemists and physicists in this country and abroad, nothing has been discovered to change or replace the methods employed by them. I do not mean to say that no improvements have been made in the methods of manufacture, but the broad principle of the mechanical application or combination of the active material with the conducting support plate, which has been awarded to Brush in this country, has not been improved upon in any way, either by further discoveries or by a totally new departure in another direction.

As this type, therefore, seems to be the one that will alone survive in the struggle for existence, let us examine

its construction a little more minutely. In the earlier forms of this battery plain sheets of lead were used and the active material or oxide of lead was simply plastered over the surface of the plate, thin sheets of felt or other insulating material were placed between the plates and then the whole number were rolled into a cylindrical form or bound together with various clamping devices. This was merely a makeshift, and at first sight to any one familiar with a Planté battery would not only have not seemed like an improvement but really a step backward. But the principle was right, and it only required a little mechanical skill to insure far better results than Planté ever obtained. Brush patented every conceivable form of plate for retaining the active material, including what is also known as the "grid" form, or Swan type; and Volkmar, Sellon and Swan, on the other side, obtained patents for various improvements over Faure. But the manufacture has finally narrowed down to one form or type, and that is the grid. Of course, there are dozens of other types of grid, some of them very ingenious, but there is really no good reason for their existence. No form of grid could be devised which gives such an enormous conducting surface for a minimum weight of material except the honeycomb or hexagonal form. and this for some mechanical reasons is impracticable to make. There is also no form that exposes such a large superficial area of active material, and in which it is brought into such close electrical contact with the conductor or grid. Such a form, moreover, admits of the nicest adjustment of the proportion of grid to active matter, for if it is desirable to lessen the weight of the grid (and thereby increase the active material) for a given thickness of plate, this can be readily done by making the cross bars farther apart or thinner in cross sectional area. The alleged advantages of the so-called thick plate batteries have not yet been fully demonstrated. A thick plate of the grid form can just as readily be made as a thin one, but merely to make a plate thicker in order to make it stronger mechanically is not sufficient. The question is not how thick or how thin should a plate be, but how thick or thin it should be in order to do the greatest amount

of work. Every one knows that a thick plate will last longer than a thin one, but how much work will it do measured in watt hours, compared with a thin one, and for the same cost?

The next question we will consider is that of filling the grids with the active material. This is a very important point in the process of manufacture, and if not properly done will give trouble subsequently in operating the battery, and diminish its life. The method usually employed by the various manufacturers of storage batteries is to mix the oxide of lead with a dilute solution of sulphuric acid until it becomes a thick paste, and then to plaster this material in the grid with a trowel, carefully removing the excess from the surface of the plate. This is rather an expensive method of filling, as it requires a man, who is more or less skilled, to properly fill the plates, and such a man can only fill from seventy to 100 plates per day. Mr. Henry G. Morris has invented an ingenious machine for doing this work, whereby two boys with one machine can fill 1,500 plates per day. The machine is an hydraulic press to which is attached a circular table with radiating arms supporting iron blocks or stands on which the grids are placed, and the grids after being filled with the proper amount of active material, are passed successively under the press and subjected to a hydraulic pressure, varying from 1,000 to 2,000 pounds per square inch. The oxides are previously mixed with a dilute solution of sulphuric acid, not in such quantities, however, as to make a paste, but sufficient to partially sulphate them, and get them into a condition very similar in physical properties to ordinary moulding sand. The oxides, after being mixed with the acid solution, are sifted through a fine sieve, in order to break up all lumps, and are then heaped upon the grid, in the form of a powder, slightly rubbed into the interstices of the grid, the excess removed with a straight edge, and then compressed. In this manner plates can be filled uniformly and accurately at a minimum cost without the personal equation which is such a large factor in hand filled plates. Another important feature in filling is the condition the active material will assume after formation.

If the oxides are mixed with a considerable quantity of dilute acid, or sufficient to make them into a paste, and then applied to the grid, a considerable proportion of their bulk is water which dries out and leaves the mass in a loose condition in the holes or spaces of the grid. There is also a further loss in volume in the negative plate after formation, owing to the reduction of the litharge, or PbO, to spongy lead. This loss amounts to eight per cent. by weight, and in some plates made in this way, that I have recently seen, which had been used for traction work, the shrinkage had become so great that when the plates were removed from the acid and allowed to dry you could actually see, by holding them up, a line of light between the active material and the grid, and in order to render them useful again they will have to be repasted. Of course, this increased the internal resistance, and diminished the efficiency of the battery. As it is the active material that does the work in a battery, this density and better electrical and mechanical contact with the grid as a result of the compression, is a valuable feature of this method of filling. In fact, the life of a battery, other things equal, is limited by the time required to wash away the peroxide of lead in the positive plates. Peroxide of lead formed in this way is non-metallic and finely divided, and when freshly formed after a full charge has very little more consistency than a hard mud. It is only after it has become sulphated by discharging the battery that it gets hard and even stony when removed from the acid and dried.

Spongy lead, on the contrary, is, of course, metallic and the particles are comparatively closely knit together and tough and horn-like.

This brings us to the process of formation, or charging as it would be more proper to call it, in the case of a Brush battery as opposed to that of a Planté. After the plates are filled they are assembled together, alternately, positive and negative, into groups of as many each as it is desirable to handle, and after temporary mounting, are placed in an acid bath and charged with a current from one-half to one ampère per pound of element. The operation is purely one of elec-

trolysis. Oxygen is liberated at the positive plate and hydrogen at the negative. The oxygen acts on the red lead and sulphate of lead in the positive plates and converts them into peroxide, the hydrogen acts on the litharge and sulphate of the negative plates, reducing them to spongy lead. It requires a continuous charge of 900 ampère hours to completely reduce the negative plates in a "17 S" accumulator, or (say) 100 ampère hours per negative plate, or, 200 ampère hours per pound of active material or litharge, each plate containing about one-half pound. Practically this is a very interesting statement aside from the battery question, as it is an exact measure of the amount of electrical power required to reduce a pound of lead from its oxide and as the E.M.F. is about 2·5 volts the amount of power required is 500 watt hours or less than three-fourths of an electrical horse-power per pound of lead. After formation the plates are washed and dried and are then permanently mounted into the various types that we have here this evening.

Having described briefly the method employed in manufacturing a battery, we will now consider the question of operating a battery, and the reactions, etc., that take place in charging and discharging, and finally the applications to which they can be applied.

It is hardly necessary for me to say that there is no actual storage of electricity in an accumulator; it is simply a convenient reservoir for storing the active ingredients necessary to generate a current of electricity. In fact, a charged battery becomes a primary battery, and the current derived from it is based on identical principles. The reaction which takes place when a battery is discharged can best be examined by referring first to a primary battery with a simple zinc-copper couple.

When a positive element like zinc is opposed to a negative element in dilute sulphuric acid, the following reaction occurs. On uniting the poles of the battery the molecules of H_2SO_4 become polarized, then the acid radical is turned towards the electro-positive element Zn and the basic ion towards the electro-negative element. Substitution then

takes place, and the sulphuric radical unites with the zinc to form a molecule of zinc sulphate, and an interchange of molecules then takes place along the line until the negative pole is reached, where hydrogen (two atoms) is liberated. This can be expressed graphically as follows:

—		+		
Electro-positive element.	Zinc.	$H_2\,SO_4$ H_2 SO_4 H_2 SO_4 polarized becomes $SO_4\,H_2$ $SO_4\,H_2$ $SO_4\,H_2$ after substitution $Zn\,SO_4$ $H_2\,SO_4$ $H_2\,SO_4$ H_2	Copper.	Electro-negative element.

Let it be supposed that at the electro-negative element, where the hydrogen is liberated, there is some substance that it can combine with or displace, then the following action takes place as in the ordinary Daniell cell:

—		+			
Electro-positive element.	Zinc.	$H_2\,SO_4$ $H_2\,SO_4$ polarized $SO_4\,H_2$ SO_4 H_2 after $Zn\,SO_4$ $H_2\,SO_4$	$Cu\,SO_4$ $Cu\,SO_4$ becomes SO_4 Cu SO_4 Cu. substitution. $H_2SO_4\,Cu\,SO_4\,Cu$	Copper.	Electro-negative element.

The first action is the polarization of the molecules; the second, a general substitution all along the line, forming zinc sulphate at one end and depositing metallic copper at the other, one atom of copper being equivalent to two atoms of hydrogen displaced in the former reaction.

With the knowledge thus gained we can now study the discharge of a secondary battery.

—		+		
Electro-positive element.	Spongy lead. $PbSO_4$	$H_2\,SO_4$ $H_2\,SO_4$ H_2SO_4 polarized becomes SO_4 H_2 SO_4 H_2 SO_4 H_2 after substitution. $H_2\,SO_4$ $H_2\,SO_4$ $H_2\,O$	Peroxide of lead. $PbSO_4$	Electro-negative element.
	The spongy lead is gradually converted into lead sulphate.		The peroxide, giving up one atom of O is reduced to protoxide which in presence of sulphuric acid is immediately converted into lead sulphate.	

In this case the polarization occurs as above and the substitution then takes place, forming a sulphate of lead on one pole, and liberated hydrogen at the other. But here there is a substance, peroxide of lead, which yields up its oxygen to the liberated hydrogen and forms a molecule of water. The oxide of lead formed by the reduction of the peroxide is, of course, instantly changed into sulphate of lead by the sulphuric acid. The action of the discharge is, therefore, to gradually sulphate both poles of the battery. Sulphate of lead, being insoluble in sulphuric acid and water, remains in the grids or support plates in place of lead and peroxide. The reaction in charging is more complex, and is not so well understood, but the final result is to leave the plates in the same condition as mentioned above before discharging. The conditions in charging, moreover, are not identical with those of discharging. It has been found that when a current from an external source is passed through two platinum plates in acid, polarization results, and oxygen is liberated at one pole and hydrogen at the other. When a secondary battery is completely discharged the plates are practically similar; that is, they are both lead plates, containing sulphate of lead. Hence, there is no difference of potential and no current results from connecting their terminals. It is, therefore, immaterial (so far as the chemical action is concerned) to which pole is connected the positive pole of the external source, which may be either a battery or a dynamo. In either case the plates now act in a manner similar to the platinum plates mentioned above, and oxygen is liberated at the pole through which the current enters and hydrogen at the opposite pole. In fact, the operation of charging is really one of simple electrolysis.

The reaction which takes place at the positive pole is

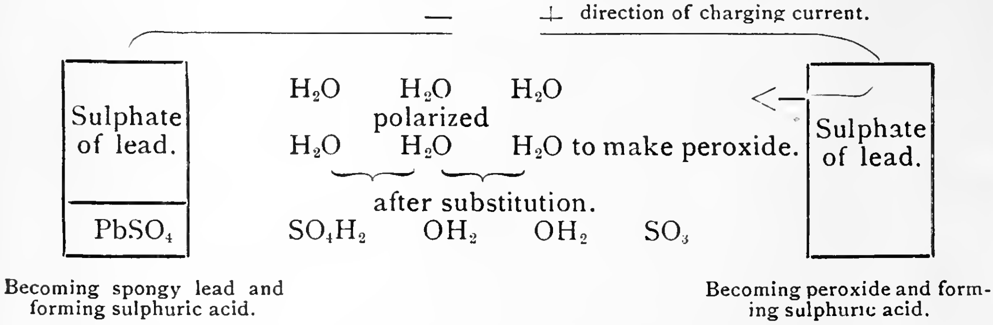
$$PbSO_4 + O + H_2O = PbO_2 + H_2SO_4$$

and at the negative pole

$$PbSO_4 + H_2 = Pb + H_2SO_4.$$

In other words, peroxide of lead is re-formed from the sulphate at one pole, spongy lead at the other and sulphuric

acid at both poles. The battery is then once more in condition to perform work. The reaction can be represented graphically as follows, the current flowing in the opposite direction from that shown above:



That sulphuric acid is formed at both poles is proved by the specific gravity of the solution after charging. What has been done, then, when a secondary battery is discharged, is to burn lead to sulphate. The amount of energy produced thereby can be determined quantitatively.

Having described the chemical reactions taking place within the cell, what I now desire to call your particular attention to and to show you, is, that a pound of zinc burned to oxide of zinc or a pound of lead burned on a grate, or in the open air to oxide of lead produces exactly the same mechanical equivalent in foot-pounds as a pound of zinc, or lead consumed in a battery and developing current produces. This fact, which was long since deduced from the doctrine of the conservation of energy, is of the highest importance to be borne in mind, if we desire to get a correct idea of electricity. It is amazing that with this doctrine of the correlation of forces, and the further fact that the intrinsic or specific energy of a pound of any substance is precisely the same whether set free as heat or electricity, that there should still be such a confusion and failure in the average mind to grasp the meaning or idea of what electricity is. There is no more mystery about electricity than there is about heat or any other force, except the one great and incomprehensible mystery of its existence, and it can as truly be defined as a "mode of motion" as heat. If a piece of zinc be placed into dilute sulphuric acid a violent

action immediately takes place with the evolution of hydrogen gas, and the generation of a definite amount of heat, or in another case if the temperature be raised sufficiently high, the zinc will combine with the oxygen in the air and burn to oxide with the generation of a definite amount of heat for every unit of weight. If, however, we connect this piece of zinc with a copper wire, the end of which is also placed into the acid, the wire becomes endowed with the extraordinary properties which are produced by what we call an electric current, and as this phenomenon appears the generation of heat in the acid disappears. In other words, the potential energy charged on the atoms or molecules of zinc is, in the act of combination of the zinc with the sulphuric radical, set free and manifests itself either as heat or electricity.

1 gram Zn to Zn O, ...	=	1,300	calories.
1,300 $\times$ 3·06 (foot-pounds per calorie) . . .	=	3,978	foot-pounds.
3,978 $\times$ 454 (grams per pound), ...	=	1,806,000	foot-pounds per pound of Zn.
1 coulomb, ...	=	·000330	grams Zn.
1 gram, ...	=	3,000	coulombs.
454 grams or 1 pound, ...	=	1,362,000	coulombs.
1,362,000 $\times$ ·74 (foot-pounds per coulomb, .	=	1,000,000	foot-pounds.
Zn giving 2 equivalents, ...	=	2,000,000	foot-pounds per pound of Zn.

Unit E.M.F. or one volt, acting through unit resistance, one ohm, gives a current of one ampère, which continued for one second yields the unit of energy, one coulomb, equal to $\frac{1}{746}$ horse-power and since one horse-power equals 550 foot-pounds of work per second, one coulomb equals $\frac{550}{746} = 0·7373$ foot-pound in a second. Electric current is measured by the amount of chemical work performed in a given time. Taking hydrogen as the unit, the amounts of the other elements set free by the same electric current are proportional to the atomic weights of the various elements compared with hydrogen as one, due allowance being made for the valency af the element under consideration. The amount of current which will release ·00001022 gram (or 0·000158 grains) of hydrogen per second is the unit of current or the ampère, and an ampère under unit conditions;

that is, at one volt and through one ohm resistance for one second, is called a coulomb. This is the real tangible part, so to speak, of electricity, and is exactly analogous to a heat unit which all engineers thoroughly understand. In fact, a coulomb is equal to 0·24 calorie or 0·74 foot-pound. It is this knowledge, therefore, that enables us to calculate theoretically the total amount of energy that can be derived from a given weight of any substance consumed electrically. That is to say, every act of chemical combination is attended with a loss of potential energy; that is, the energy becomes kinetic, is set free and manifests itself as heat, electricity, or motion. The converse of this proposition is likewise true, that every act of chemical decomposition requires a supply of energy exactly equal to the amount lost or set free in making the substance which is to be decomposed, and this energy disappears as potential energy charged on the atoms or molecules of the substances decomposed. The energy derived from the substitution of lead for hydrogen in sulphuric acid in the above reactions, is the source of the E.M.F. of the battery, and the amount or actual weight of lead consumed represents the current which will be produced, measured in coulombs.

Now the atomic weight of lead is 207. Lead being a dyad, its electrical equivalent is 103·5 and 103·5 $\times$ ·00001022 = ·001058 gram. In other words, the consumption of ·001058 gram of lead in a battery furnishes a current of electricity of one ampère for one second or one coulomb, or one coulomb will deposit ·001058 gram of lead. One gram of lead, therefore, equals 944 coulombs (1 ÷ .001058 = 944). In an accumulator of the "17 S" type containing nine negative and eight positive plates, there is nearly five pounds of spongy lead, and since five pounds equals 2,273 grams, 2273 $\times$ 944 = 2,145,712 coulombs. Dividing by 3,600 (number of seconds in an hour), we have 586 (say 600 ampère hours at one volt pressure), as the theoretical capacity of the accumulator, or about eight-tenths of a horse-power hour. This would be equivalent to 300 ampère hours at two volts, the normal working pressure of a lead peroxide battery, and corresponds almost exactly with the amount obtained from the

total discharge of a pile. It is, however, only rated as a 150 ampère hour pile, because in practice a total discharge is never accomplished.

This is a matter of the first importance as it enables us at once, without a practical test, to form a correct judgment as to the truth of claims that may be made as to the capacity and efficiency of any given battery.

Having now examined, briefly, the mode of operation of a battery, we come finally to consider its application for various purposes.

The first use to which storage batteries were applied was electric lighting. When the modern type of storage battery was first introduced it was hailed as the evolution of the great problem of electrical distribution, and we were informed by many, who should have known better, that our houses and offices would soon be lighted by batteries which would be carted around and delivered in much the same fashion as ice and coal is to-day, but the fact is that a storage battery is a very expensive thing for the amount of its storage capacity, and even after the investment is made the expense of maintaining the battery in first-class working order is still very considerable, amounting probably to twenty-five per cent. per annum of its first cost. For example, a fifty-light plant costs about $1,000, and $250 per annum to maintain, irrespective of the cost of charging and generating machinery. You can readily understand, therefore, why you are not all enjoying the luxury of electric lights in your houses at the present time. At the same time, a storage battery is so essential for a complete isolated electric light installation, that its use is growing every day, and with its growth the first cost will undoubtedly diminish, and where properly employed, the cost of maintenance be reduced to a minimum, perhaps as low as five per cent. per annum.

Let us see how we estimate for equipping a fifty-light plant. In the first place, the voltage of the lamps must be considered. If a 100-volt lamp, fifty accumulators must be used in series, as each gives but two volts. One hundred-volt sixteen candle-power lamps require about 0·6 ampères each, and

fifty would, therefore, require thirty ampères. We must, therefore, select a type of accumulator large enough to stand such a high rate of discharge, for a comparative long period of time, without injury. We use for this purpose type "15 I." Of course, very much larger currents can be obtained from such a battery, but it is only done at the expense of the life of the pile.

You can readily understand how it may be very economical to run a batttery in connection with a direct lighting plant. Suppose, for example, there is a 1,000-light plant to be installed, and the number of hours in the day during which the entire load, or maximum load, is used is only three, then if this plant of 100 horse-power must be kept in operation to feed fifty or 100 lights for the balance of the twenty-four hours, it can only be done at a great sacrifice of economy. In such a case a storage battery, properly installed, instead of being a source of expense, is really an economy and renders the cost of operating the plant considerably less.

It is also absolutely indispensable for isolated domestic lighting apart from a central station.

The second important use to which storage batteries have been successively applied is in connection with central station lighting. Very little or anything has been done in this country in this direction up to the present time, although arrangements are now being perfected that will insure within a short time a successful demonstration of the value of storage batteries in central station lighting. The conditions under which the central station plants are now operated are such as to render it impossible to effect economical distributions. This may be illustrated by the accompanying diagram, showing the load curve of a central station.

It will be seen from an inspection of the same, that the maximum load only lasts for a few hours per day, yet in order to provide for this load the generating machinery must be sufficient to supply the same, even if only employed for an hour. This entails a much larger investment than is really absolutely necessary, and an additional number

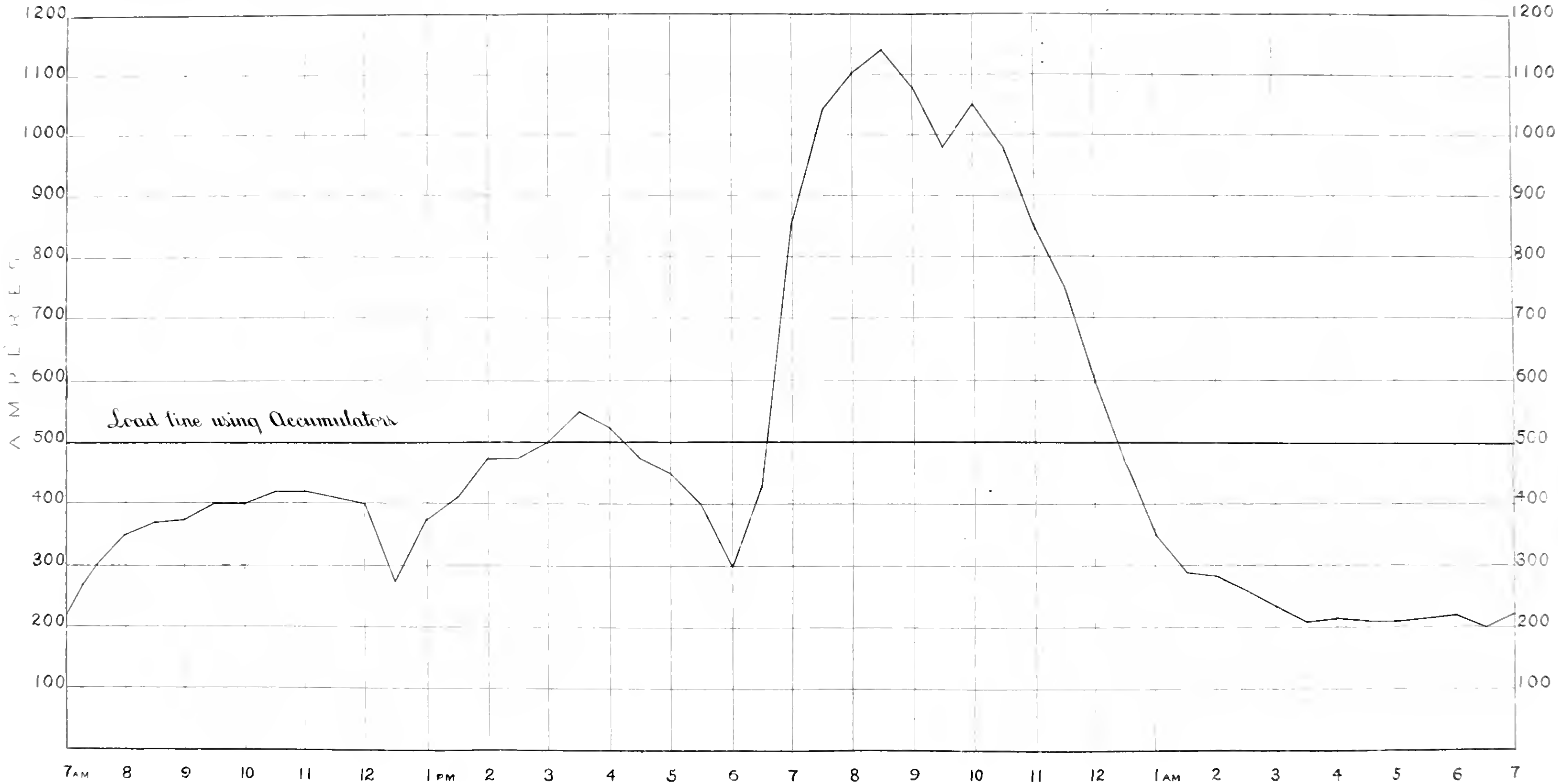


DIAGRAM OF LOAD ~ ATLANTIC CITY ELECTRIC LIGHT STATION.

of small dynamos to take care of the load during the hours of minimum demand. Whereas, by the use of storage batteries, larger units of power may be installed and worked at their maximum output and efficiency during the entire twenty-four hours.

The even line shows how the curve would appear in the same central station by employing storage batteries.

In other words, by employing generating machinery with a maximum load of 500 ampères for the twenty-four hours, using the surplus power for charging the batteries, the power plant, in this case, could be cut down at least one-half.

Storage battery installations may be made in such cases with a capacity of from 3,000 to 5,000 ampères for from three to ten hours, as may be desired. By such means the load curve can be reduced to almost a straight line, which would mean, of course, the maximum efficiency of a plant at the minimum cost of operating. There are many such central station plants in Europe successfully operated by the Tudor battery, which is a special type of the Brush battery, but the limits of a lecture will not permit of any detailed description of the same.

The third important use to which storage batteries may be applied is in mechanical traction, for the propulsion of street cars and other vehicles. I have already given you, on former occasions, many of the particulars connected with this work in this and other countries, and notwithstanding the apparently unfortunate results connected with the attempts to make street-car traction commercially successful, I desire to place myself on record as predicting that ultimately storage battery traction will entirely supersede the trolley for street-car service. Of course, for suburban and country roads the trolley will occupy its legitimate field. For other purposes of traction, such as the movement of carriages, wagons, etc., the storage battery can alone be used. One of the most successful applications of storage batteries is the running of electric launches. This is really an ideal method of running a small boat or pleasure launch, and the fact that this method has been

selected above all others, after a most severe competitive trial, to run all the boats on the lagoons at the World's Columbian Exposition in Chicago, this year, is the most striking evidence of the degree of perfection obtained in this branch of the industry.

Finally storage batteries are successfully used for an infinite number of minor purposes, of which it will only be necessary to enumerate a few of the more striking examples, viz: The operation of phonographs, sewing machines, dental engines, dental and surgical instruments, telegraph and telephone lines, call bells, small motors and lamps, electro-chemical and metallurgical operations, electric welding, and a host of others.

From the above it must be evident to the dullest observer that storage batteries are destined to play an ever increasing and important part in the development of electrical science, and, therefore, a careful and conscientious study of the principles underlying their construction and application is worthy of the efforts of the best electrical talent, apart from the intense interest the operation of the batteries themselves possess, being connected, as it were, with the very genesis of electricity itself.

COPPER MINING IN THE UNITED STATES.

BY C. KIRCHHOFF, Editor of *The Iron Age.*

[*A lecture delivered before the Franklin Institute, February 20, 1893.*]

The lecturer was introduced by the Secretary of the Institute and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Americans have grown so thoroughly accustomed to claiming preëminence in industrial achievements, that little comment is now created when one after the other branch of production pushes forward into the first rank, so far as quantity of output is concerned.

The utilization of our great mineral resources has pro-

gressed so rapidly in the past decade that we accept, in a matter-of-fact manner, attainments over which we might have been wildly excited ten or fifteen years ago.

We are now the greatest producers of iron ore, pig iron and steel. We are far ahead of any country in our output of lead; have poured enormous quantities annually of precious metals into the coffers or the world. Probably before the end of this century we shall raise more mineral fuel than Great Britain, and outstrip all other nations in the manufacture of spelter.

We have thus taken the first step towards industrial preeminence in nearly all branches of mining and metallurgy, but it is really only in one in which we have progressed *beyond* that point, and that is, in the production of copper. I take it that, commercially, our *first* aim must be to cover our own rapidly increasing requirements; the *second* must be to capture as large a share as we can of the markets of the world, consistent with reasonable husbanding of our resources.

Naturally, at first, the products of our mines go out in the cruder form, and it is in that stage of our development that we are now in the copper trade. Our manifest destiny is, however, to do more and more the work of converting the raw article into the finished product for the consumer, and make the world pay us tribute not alone for our vast resources, but also for energy, skill and taste as manufacturers and for enterprise and ingenuity as traders. It will be a grand struggle, in which those qualities which have won for us the contest for our own home markets will assure to us the victory in distant fields.

Permit me to sketch for you this evening, in rough outline, the main features of the development in one relatively small branch of our mining industry. Let me make a brief inventory of our resources; let me show you how one by one our principal districts rushed into prominence, carrying our country not alone to the rank of the greatest copper producer of the world, but making it also one of the principal contributors to and by far the most influential factor in the world's markets.

The first copper mine worked in the United States appears to have been the Simsbury, near Granby, Conn., a company having been formed in 1709. Ten years later the Schuyler mine, near Belleville, N. J., was discovered, and with a number of others in that vicinity was worked for a number of years. In fact, the first steam pumping plant erected in this country was probably that used by Josiah Hornblower, in 1753, at the Belleville mine. Pennsylvania entered the ranks with the Gap mine, in Lancaster County, in 1732. It does not appear, however, that any work of moment was done until the middle of the present century. The Ely mine, in Vermont, which had been discovered in 1820, began to be worked only in 1850, and from then on till 1880 was a factor. The Ducktown group of mines in Tennessee, now being re-opened, were discovered in 1846, but produced heavily only a few years later. Late in the fifties and early in the sixties, California shipped relatively heavy quantities, but dropped back to an insignificant place after the exhaustion of the richer surface ores. While they contributed important quantities at that time to the country's store of the metal, the mines of the Atlantic and the Pacific coasts soon dropped to a minor position before the rising glory of the Lake Superior district.

The existence of copper in the native state on Lake Superior was mentioned as early as 1659 or 1660, in the *Relations des Jesuites*, and Father Claude Allouez described a stray mass in 1666. In 1771, Alexander Henry organized a company in England to mine copper on the Ontonagon River, Charles Townshend, Duke of Gloucester, and others, being incorporators. Failing to find copper in place, Henry renewed operations in 1772 on Michipicóten Island, on the north shore of Lake Superior, but only to score another failure. For nearly three-quarters of a century the copper resources of Lake Superior failed to attract attention, until in 1841, Dr. Houghton gave the world the first authentic and scientific account of the geology of the Keweenaw series and of the occurrence of the native copper. The first mine, the Cliff, was opened in 1844, and in the next year Lake Superior copper first made its appearance in the markets of

this country, which it was destined to dominate for so many years, particularly when the Calumet and Hecla, which first appeared as a producer in 1867, began to pour forth its metal.

That position the Lake mines held until, in 1881, when the Union Pacific road opened the necessary transportation facilities for the Butte District of Montana, and the Southern Pacific completed its road into Arizona and New Mexico. Since then there have been years of almost bitter struggle for supremacy between the Montana and the Michigan districts particularly, and the output has increased at a tremendous rate.

Leaving out of account a number of scattered sources of supply, furnishing considerable metal in the aggregate, but individually unimportant, the producing mines of this country may be classed in three groups, each possessing its special features, each enjoying some advantages and suffering under some drawbacks. The development of each of them has been attended with characteristically American disregard of precedent in older countries, with its attendant record of disastrous failures, but also with that bold and ingenious adaptation of original means to an end, which is the wonder of Europeans in so many American industrial enterprises. In the light of subsequent events, the commercial policy and the technical management of many prominent American copper mining undertakings may easily be criticised with much show of wisdom. But in its broader lines, considering the commercial and technical limitations, the development of the industry is one of which Americans may justly be very proud.

The three groups referred to are the Lake Superior, the Butte, Montana and the Arizona; the first working an ore containing the copper in native form; the second yielding sulphuret ores containing some silver; and the third depending chiefly upon oxidized ores. Permit me to take them up in turn, prefacing with the general remark that, generally speaking, copper as a mineral is very much in evidence. Its oxides and carbonates possess a brilliant coloring, so that in regions like our Rocky Mountain terri-

tories prospectors have been quick to report their finds. Up to the present time, there are no sections of the country promising important new developments, except possibly the Seven Devils district in Idaho.

THE LAKE SUPERIOR MINES.

In the Lake Superior district, the deposits first to attract attention were what is known as the mass mines, which worked either on the transverse fissure veins of Keweenaw County towards the point of the promontory, or on the interbedded veins of the Ontonagon country, towards the base of the promontory. The early famous mines belonged to this class, among them the Cliff, the Minnesota, the Central, and others. The copper is found in great sheets or masses, at times many hundreds of tons in weight, the Minnesota having a record of one mass of 500 tons, while a series of related masses in the Central yielded 1,200 tons of native copper. The cutting up of these great bodies of tough, metallic copper was a very laborious and costly undertaking. With greater depth the veins appeared to become leaner, and practically to-day the famous old mass mines have ceased to play any part.

With the exception of the Central, all the important mines of the district are now working one of two classes of deposits interbedded in a lava in what is locally known as trap, the *amygdaloid* beds and the *conglomerate* beds. They dip westerly towards Lake Superior at an angle varying between 30° and 50°. In them a part of the original mineral constituents have been displaced by native copper. The principal difference, from a practical point of view, between the two classes of beds, is that the amygdaloids are usually softer, and can therefore be more cheaply worked, while the conglomerate rock is much harder, and therefore requires a richer ore to pay.

The amygdaloid mines were first opened in 1851, the Copper Falls being the pioneer. To-day the most important concerns working on amygdaloid deposits are the Quincy, the Franklin and the Atlantic. It was not until 1864 that the Albany and Boston Company attempted to work a con-

glomerate bed, followed in 1865 by the most famous of the Lake mines, the Calumet and Hecla. The story is told that the attention of a camping party was called to a pig rooting in a shallow excavation, which proved to be a pit dug by a prehistoric miner. The mine thus revealed has given to its stockholders, on $100,000, nearly $40,000,000 in dividends, with more to come.

The stories of the great masses of native copper found in the Lake Superior district have created the impression that the yield of the ore is very great. As a matter of fact, the rock is really very poor. Thus the Atlantic, an amygdaloid mine, has contrived to live, and pay moderate dividends, on a yield of only 0·60 to 0·70 per cent. of copper, while the Quincy, the richest of this class, can claim only two per cent. from sorted rock. The Calumet and Hecla from its richest ground takes only four and one-half per cent. ore, the average being near three and one-fourth per cent. It is true that at times very rich places are encountered. I myself, in a tour of the mine, visited one face where the men working on contract were thoroughly disgusted because they had started a number of drill holes, only to abandon them because they were being forced to punch their way through solid metal.

The persistency of both the amygdaloid and conglomerate beds in depth and in metal-bearing, has been pretty thoroughly proven by a number of deep shafts. The Quincy is down to its 4,000-foot level, on the incline, while the Calumet and Hecla is little less than that. It was proven, too, in a most striking manner, by the bold undertaking of the Tamarack Company, conceived by John Daniell and his associates in Boston. Early in 1882, a vertical shaft was started, when the lower drifts of the neighboring Calumet and Hecla were far above the level at which the Tamarack shaft was expected to pierce the lode. In 1885, at a depth of 2,270 feet, the bed was struck, carrying an excellent percentage of copper. The mine paid from the start, and has contributed to its stockholders, thus far, over $3,000,000. Its success and the manifest advantages of vertical shafts over inclines for deep work, have led to

further work in this direction, so that there are now sunk, or sinking, seven shafts, of which the deepest will reach the lode in 5,000 feet, or nearly a mile.

In the mining operations proper there is nothing particularly novel or striking in the Lake Superior district. The use of rock-drilling machinery and high explosives has made it possible to break rock at a low cost, and has, it might almost be said, created the great operations of the present day. In some of the mines, a good deal of poor rock is sorted out and stowed away underground. In others, notably in the great mines on the conglomerate, the whole of the bed is taken out, which calls for an enormous amount of timbering.

It was in the subsequent working of the copper rock that American facility in meeting unusual conditions manifested itself. The problem of extracting native metal from rock had not presented itself elsewhere. It was the introduction of the Ball steam stamp—a clever adaptation, to the special purpose, of the Nasmyth hammer—which solved the question. Its later history has curiously illustrated, too, how dangerous a guide long-established practice may be. For nearly a generation the mortars were placed on a carefully prepared foundation of spring timbers, the idea being that a certain amount of elasticity was essential. A few years since, it occurred to one of the stamp-mill superintendents that it might be wiser to make a solid foundation. The result showed a marked increase in efficiency, and now spring timbers are rapidly going out of use.

The rock, as it comes from the mine, is crushed in the steam stamp mills, and is then jigged, the finer material being washed on buddles. I shall be able to show you photographs of some of this machinery in dealing with one of the leading Montana mines.

One or two photographs will best serve to give you an idea of the topography of the copper country. I shall couple with it photographs of some of the great Calumet and Hecla machinery, which has a special interest for Philadelphians, because nearly every one of these giants was built in your city.

THE MONTANA MINES.

Butte, Mont., first attracted attention as a silver camp, and the story goes that its greatest producer, the Anaconda, was first opened in the hope that it would yield the bright metal. Marcus Daly, the discoverer and one of the principal owners of the property, assures me that there is no foundation for this tale. Still, the silver mines were famous long before the copper deposits were worked. The veins, which have raised Butte to the rank of the greatest mining camp of the country, are enclosed within a rectangle, having a length of two and one-half miles and a width of about one mile. At its eastern end the mines are argentiferous, copper predominating in the west. A very large number of veins course through the granite hill, and more are being gradually discovered under the wash at its base. At the surface the copper contents were relatively low, while the silver was present in greater quantity. But at the water line, at a depth of 50 to 150 feet, the vein filling changed somewhat suddenly in character, being heavily charged with copper sulphurets, copper glance and peacock copper predominating. A good many of the veins are large, their thickness rising to over 100 feet, although the average does not probably go above seven or eight feet. The great mass of the ore is not rich, running from four to ten per cent. of copper, but enormous quantities of very rich ore, carrying from twenty-five to thirty-five per cent. of copper have been mined. In fact, the greatest shock which the copper markets of the world sustained was that growing out of the sudden shipments to England, by the Anaconda mine in Butte, of many thousands of tons of rich ore.

While there is a large number of individual mines, the copper mining and reduction interests of Butte are in relatively few hands, the prominent companies being the Anaconda, Boston and Montana, Butte and Boston, Parrott, and the Butte Reduction Works.

The development of the camp soon proved that its future must rest rather on the successful utilization, commercially and technically, of the abundant stores of low grade ores,

than upon the extraction of occasional bunches of rich ground. The mining presents little difficulty except that growing out of the excavation of great openings in such mines as the Anaconda and St. Lawrence, where rock filling has now become the main reliance. Some trouble is also encountered in the sliding of the ground, due to intense mining operations in a relatively small territory.

A good deal of experimenting, however, grew out of the efforts to dress the ores to a higher percentage. The German system of concentration by crushing, screening and jigging was developed in some plants, while others, notably the Anaconda, adopted the Lake Superior methods and appliances.

The earlier plants were located at Butte, but the Anaconda was the first to undertake the treatment of the ores at another locality. It was followed later by the next largest concern, the Boston and Montana, which built a great concentrating and smelting plant at Great Falls, Montana, where water power in abundance, at low cost, was available.

The ore after it is concentrated goes to the smelting works. First, it is roasted, to drive off a part of the sulphur, either in open stalls, which have enveloped Butte in a cloud of smoke, against which there was a vigorous popular protest, or in reverberatory or rotary calcining furnaces.

The roasted ore is either smelted in reverberatory furnaces or in blast furnaces, the product being a sulphide of copper and iron, or matte, carrying from fifty to sixty-five per cent. of copper. Some of the photographs which I will show you will give you an idea of the character of this plant.

The great bulk of the product of the Montana mines is being shipped to Eastern refiners and works in England, as matte.

All of the Butte copper ores carry varying quantities of silver. In some cases the silver is of so much importance that copper is really only a carrier for the more precious metal, accompanying it through all the operations until it is finally separated. The Williams smelter concentrates the silver in a high grade copper matte, which is shipped to

Denver to the parent company, the Boston and Colorado Company, where the two metals are separated by Pearce's methods and the Ziervogel process.

A somewhat different procedure is followed at the other works, and promises to become the characteristic method of Butte. The Parrott Company was the first to adopt the Manhes method of bessemerizing copper matte for the elimination of the sulphur and the production of a "blister" copper, or high grade metallic copper. The Anaconda and the Boston and Montana have followed the example thus set, the former in an experimental plant, and the latter in their new Great Falls works, in which the smelting department with its tilting reverberatories and arrangement of Bessemer plant clearly shows the influence of American steel practice due to the efforts of Henry Aiken, of Pittsburgh, who acted as consulting engineer.

The product of the bessemerizing is a metallic copper which is cast into slabs. These carry from fifty to 150 ounces of silver to the ton. This is separated by the electrolytic method. Until lately this has been done either by works in the East identified with the Montana mines, as in the case of the Bridgeport Copper Company, which is affiliated with the Parrot, or by independent copper refiners, like the Orford, Baltimore, Chicago, and others at home, or the Vivians and other smelters abroad. Lately, however, the Anaconda has been operating an experimental plant, and the Boston and Montana is building a large refinery at Great Falls. When the plans of American producers are fully developed, the exports of matte will probably cease, and the work of turning out the ingot copper and wire bars will be entirely performed in this country.

The electrolytic refining plants are surrounded with a good deal of mystery at the present time and access to them is not easily obtained.

The argentiferous copper is cast into anodes, which are suspended, covered with bagging, in vats containing an acidulated solution of sulphate of copper. The cathodes are copper sheets. By the passage through the vats of an electric current, the copper is dissolved from the anodes and

deposited on the cathodes, the silver remaining behind in the bags as a mud, with what impurities the copper may contain. The current at Anaconda is one of 950 ampères and fifty to sixty volts. The deposited copper must be remelted, refined, and cast into bars or ingots.

THE ARIZONA MINES.

The third important group of copper mines is that of Arizona, whose resources became available when in 1881 the railroads began to enter the territory. What distance from supplies and markets means is well illustrated by the fact that the Longfellow, which began work late in the seventies, had to cart its copper 700 miles to the nearest railroad station in Kansas. The high cost of fire-brick, $1 a piece delivered, led to the introduction of the water-jacketed furnace, then untried in copper smelting, the first jackets being cast of copper on the spot. Since then their use has become general in dealing with oxidized ores in the blast furnace. Nearly all of Arizona copper comes from three districts, the Bisbee, the Clifton and the Globe. A good deal of mining excitement attended the early development and wild stories of the richness of the ores were utilized to float all sorts of schemes. Now the production comes from a very small number of companies operating on a large scale. The characteristic feature of the ores of the three leading Arizona districts is that the ores are oxides and carbonates, from which copper, ninety-five to ninety-seven per cent. fine, can be obtained in the one operation of smelting in the blast furnace. This copper is of exceptional purity, and is shipped to refiners on the Atlantic seaboard, to be converted into ingots and bars. In all the three districts, the ore occurs in or adjacent to carboniferous limestones, the decomposition due to the infiltration of surface waters having extended to the depths thus far reached, although bodies of unaltered sulphuret ores are occasionally met with. The mines have opened large bodies of rich ores, but on the whole the average copper contents is not as high as is usually stated. The furnace yield of sorted ore ranges from about eight per cent. at the Bisbee mines, to twelve

and fifteen per cent. at some of the others, the closeness of the sorting depending upon cost of fuel, etc.

Besides the metal produced by the three principal districts, quite a considerable quantity of copper is obtained from scattered sources. Principal among these, not easily traceable, is that which is obtained as an incidental product of the lead smelting operations in different parts of the Rocky Mountain regions. A somewhat curious circumstance is the discovery, in the sulphuret deposits of some of the deeper Leadville mines, of notable quantities of copper. A large quantity of the metal is also smelted from imported and domestic pyrites used in the manufacture of sulphuric acid.

Each of the three great districts possesses advantages of some importance. The lake still retains its preëminence in the quality of its product, followed closely, however, by the Arizona product.

The bessemerizing, coupled with the electrolytic method, has, however, made it possible to produce from impure raw material a high quality metal, so that the absence of arsenic, sulphur and other substances in the ore mined has not the great advantage which it once was.

On the question of cost the Census has established figures which still hold good. The average yield of the Michigan ore treated was 1·797 per cent., the cost of mining being 8·55 cents per pound. Montana on a 7·002 per cent. ore shows a 3·27 cents mining cost, while Arizona follows with 10·079 per cent. ore and a 3·66 cents mining cost.

The Lake mines yield an ore, the crushing and washing of which furnishes a high grade product. These operations cost 0·59 cent per pound, and the refining and marketing adds about 1·60 cents per pound more, making the total 10·74 cents per pound.

The Census report shows that the cost of concentrating and smelting in Montana was 6·16 cents per pound. The cost of shipment and of refining probably carries this to about 11 cents per pound. Later returns for silver and better equipment probably reduce this cost.

The Arizona mines add 4·01 cents for concentrating and

smelting to the mining cost, making 7·67 cents for the blister at furnace. The cost of transportation carries this near 10 cents per pound at New York.

CONCLUSION.

During the periods of adversity and trial which the copper industry of the United States has undergone during the past decade, its three great districts have proven their ability to live in competition with all the producers of the world, in spite of relatively high wages and great distance from market. In fact, the broad statement may be made that the larger and richer mines can pay comfortable dividends to their stockholders when the great German, Spanish, Australian and Japanese mines are finding it difficult to make ends meet. The probability is that additional economies in mining, milling, smelting, refining and marketing will more than compensate for the naturally advancing cost due to deeper mining. In fact, it seems probable that at no distant day deposits hitherto considered too poor may be profitably operated.

We are undoubtedly making tremendous inroads annually into the reserves of our known mines, and during the past few years no finds of consequence have held out the hope that there will be new claimants to fame. Still, there is a good deal of ground yet unprospected in the Lake Superior district, and great new discoveries are still among the possibilities. In the Rocky Mountains there are known large deposits as yet inaccessible, which promise to fill any coming gaps. For the near future the position of the United States as the grandest copper producer is assured. We shall remain the leaders for some time to come.

On LIGHT and other HIGH FREQUENCY PHENOMENA.*

By Nikola Tesla.

[*Continued from p. 279.*]

If a wire or filament be immersed in a homogeneous medium, all the heating is due to true conduction current, but if it be enclosed in an exhausted vessel the conditions are entirely different. Here the gas begins to act and the heating effect of the conduction current, as is shown in many experiments, may be very small compared with that of the bombardment. This is especially the case if the circuit is not closed and the potentials of course very high. Suppose a fine filament enclosed in an exhausted vessel be connected with one of its ends to the terminal of a high tension coil and with its other end to a large insulated plate. Though the circuit is not closed, the filament, as I have before shown, is brought to incandescence. If the frequency and potential be comparatively low, the filament is heated by the current passing *through it*. If the frequency and potential, and principally the latter, be increased, the insulated plate need be but very small, or may be done away with entirely; still the filament will become incandescent, practically all the heating being then due to the bombardment. A practical way of combining both the effects of conduction current and bombardment is illustrated in *Fig. 24*, in which an ordinary lamp is shown provided with a very thin filament which has one of the ends of the latter connected to a shade serving the purpose of the insulated plate, and the other end to the terminal of a high tension source. It should not be thought that only rarefied gas is an important factor in the heating of a conductor by varying currents, but gas at ordinary pressure may

* A lecture delivered before the Franklin Institute, at Philadelphia, February 24, 1893, and before the National Electric Light Association, at St. Louis, March 1, 1893.

become important, if the potential difference and frequency of the currents is excessive. On this subject I have already stated, that when a conductor is fused by a stroke of lightning, the current through it may be exceedingly small, not even sufficient to heat the conductor perceptibly, were the latter immersed in a homogeneous medium.

From the preceding it is clear that when a conductor of high resistance is connected to the terminals of a source of high frequency currents of high potential, there may occur

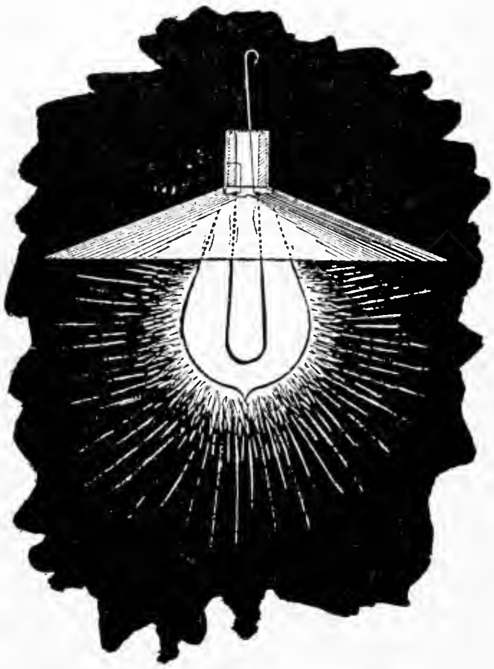


FIG. 24.—Utilizing the heating effect of conduction current and bombardment.

FIG. 25.—Illustrating lateral diffusion.

considerable dissipation of energy, principally on the ends of the conductor in consequence of the action of the gas surrounding the conductor. Owing to this, the current through a section of the conductor at a point midway between its ends may be much smaller than through a section near the ends. Furthermore, the current passes principally through the outer portions of the conductor, but this effect is to be distinguished from the skin effect as ordinarily interpreted, for the latter would or should occur also in a continuous incompressible medium. If a great many incandescent

lamps are connected in series to a source of such currents, the lamps at the ends may burn brightly, whereas those in the middle may remain entirely dark. This is due principally to bombardment, as before stated. But even if the currents be steady, provided the difference of potential is very great, the lamps at the ends will burn more brightly than those in the middle. In such case there is no rhythmical bombardment and the result is produced entirely by leakage. This leakage, or dissipation into space, when the tension is high, is considerable when incandescent lamps are used, and still more considerable with arcs, for the latter act like flames. Generally, of course, the dissipation is much smaller with steady, than with varying currents.

I have contrived an experiment which illustrates in an interesting manner the effect of lateral diffusion. If a very long tube be attached to the terminal of a high frequency coil, the luminosity is greatest near the terminal and falls off gradually towards the remote end. This is more marked if the tube is narrow.

A small tube about one-half inch in diameter and twelve inches long, *Fig. 25*, has one of its ends drawn out into a fine fibre f nearly three feet long. The tube is placed in a brass socket T, which can be screwed on the terminal T_1 of the induction coil. The discharge passing through the tube first illuminates the bottom of the same, which is of comparatively large section; but through the long glass fibre the discharge cannot pass. But gradually the rarefied gas inside becomes warmed and more conducting and the discharge spreads into the glass fibre. This spreading is so slow, that it may take half a minute or more until the discharge has worked through up to the top of the glass fibre, then presenting the appearance of a strongly luminous thin thread. By adjusting the potential at the terminal, the light may be made to travel upwards at any speed. Once, however, the glass fibre is heated the discharge breaks through its entire length instantly. The interesting point to be noted is that, the higher the frequency of the currents, or, in other words, the greater relatively the lateral dissipation, the slower will be the rate at which the light be made to

propagate through the fibre. This experiment is best performed with a highly exhausted and freshly made tube. When the tube has been used for some time the experiment often fails. It is possible that the gradual and slow impairment of the vacuum is the cause. This slow propagation of the discharge through a very narrow glass tube corresponds exactly to the propagation of heat through a bar warmed at one end. The more quickly the heat is carried away laterally the longer will be the time required for the heat to warm the remote end. When the current of a low frequency coil is passed through the fibre from end to end, then the lateral dissipation is small and the discharge instantly breaks through almost without exception.

After these experiments and observations which have shown the importance of the discontinuity, or atomic structure, of the medium, and which will serve to explain, in a measure at least, the nature of the four kinds of light-effects producible with these currents, I may now give you an illustration of these effects. For the sake of interest I may do this in a manner which to many of you might be novel. You have seen before that we may now convey the electric vibration to a body by means of a single wire or conductor of any kind. Since the human frame is conducting I may convey the vibration through my body.

First, as in some previous experiments, I connect my body with one of the terminals of a high-tension transformer and take in my hand an exhausted bulb which contains a small carbon button mounted upon a platinum wire leading to the outside of the bulb, and the button is rendered incandescent as soon as the transformer is set to work (*Fig. 26*). I may place a conducting shade on the bulb which serves to intensify the action, but this is not necessary. Nor is it required that the button should be in conducting connection with the hand through a wire leading through the glass, for sufficient energy may be transmitted through the glass itself, by inductive action, to render the button incandescent.

Next I take a highly exhausted bulb containing a strongly phosphorescent body, above which is mounted a small plate

of aluminum on a platinum wire leading to the outside, and the currents flowing through my body excite intense phos

FIG. 26.—Incandescence of a solid.

FIG. 27.—Phosphorescence.

FIG. 28.—Incandescence or phosphorescence of rarefied gas.

FIG. 29.—Luminosity of gas at ordinary pressure.

Illustrating four kinds of light effects produced by high frequency currents of high potential.

phorescence in the bulb, *Fig. 27*. Next, again I take in my hand a simple exhausted tube, and in the same manner the

gas inside the tube is rendered highly incandescent, or phosphorescent, *Fig. 28*. Finally, I may take in my hand a wire, whether it be bare, or covered with thick insulation, is quite immaterial, when the electric vibration is so intense as to cover the wire with a luminous film, *Fig. 29*.

A few words must now be devoted to each of these phenomena. In the first place, I will consider the incandescence of a button, or of a solid in general, and dwell upon some facts which apply equally to all these phenomena. It was pointed out before that when a thin conductor, such as a lamp filament, for instance, is connected with one of its ends to the terminal of a transformer of high tension, the filament is brought to incandescence partly by a conduction current and partly by bombardment. The shorter and thicker the filament the more important becomes the latter, and finally, reducing the filament to a mere button, all the heating must practically be attributed to the bombardment. So in the experiment before shown, the button is rendered incandescent by the rhythmical impact of freely movable small bodies in the bulb. These bodies may be the molecules of the residual gas, particles of dust, or lumps torn from the electrode; whatever they are, it is certain that the heating of the button is essentially connected with the pressure of such freely movable particles, or of atomic matter in general, in the bulb. The heating is the more intense the greater the number of impacts per second and the greater the energy of each impact. Yet the button would be heated also if it were connected to a source of a steady potential. In such a case electricity would be carried away from the button by the freely movable carriers or particles flying about, and the quantity of electricity thus carried away might be sufficient to bring the button to incandescence by its passage through the latter. But the bombardment could not be of great importance in such case. For this reason it would require a comparatively very great supply of energy to the button to maintain it at incandescence with a steady potential. The higher the frequency of the electric impulses, the more economically can the button be maintained at incandescence. One of

the chief reasons why this is so, is, I believe, that with impulses of very high frequency there is less exchange of the freely movable carriers around the electrode, and this means, that in the bulb the heated matter is confined more rigorously to the neighborhood of the button. If a double bulb, as illustrated in *Fig. 30*, be made, comprising a large globe *B* and a small one *b*, each containing as usual a filament *f*, mounted on a platinum wire w and w_1, it is found, that if the filaments *f f* be exactly alike, it requires less energy to keep the filament in the globe *b* at a certain degree of incandescence, than that in the large globe *B*. This is due to the confinement of the movable particles around the button. In this case, it is also ascertained, that the filament in the small globe *b* is less deteriorated when maintained a

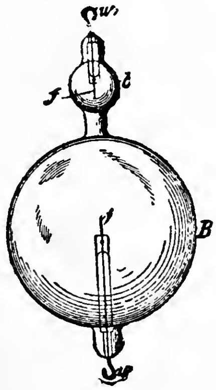


FIG. 30.—Showing the effect of confining the gas around the electrode.

certain length of time at incandescence. This is a necessary consequence of the fact that the gas in the small bulb becomes strongly heated and, therefore, a very good conductor, and less work is then performed on the button, since the bombardment becomes less intense as the conductivity of the gas increases. In this construction, of course, the small bulb becomes very hot and when it reaches an elevated temperature the convection and radiation on the outside increase. On another occasion, I have shown bulbs in which this drawback was largely avoided. In these instances a very small bulb, containing a refractory button, was mounted in a large globe and the space between the walls of both was highly exhausted. The outer large globe remained comparatively cool in such

constructions. When the large globe was on the pump and the vacuum between the walls maintained permanent by the continuous action of the pump, the outer globe would remain quite cold, while the button in the small bulb was kept at incandescence. But when the seal was made, and the button in the small bulb was maintained incandescent some length of time, the large globe also, would become warmed. From this I conjectured that if vacuous space (as Professor Dewar finds) cannot convey heat, it is so merely in virtue of our rapid motion through space, or, generally speaking, by the motion of the medium relatively to us, for a permanent condition could not be maintained without the medium being constantly renewed. A vacuum cannot,

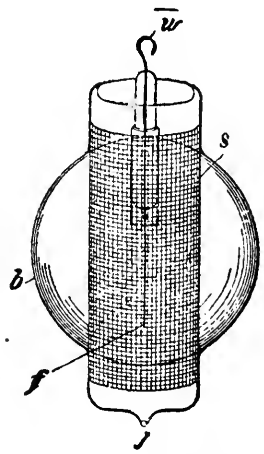


FIG. 31.—Showing the inefficiency of a metal screen.

according to all evidence, be permanently maintained around a hot body.

In these constructions, before mentioned, the small bulb inside would, at least in the first stages, prevent all bombardment against the outer, large globe. It occurred to me then to ascertain how a metal sieve would behave in this respect, and several bulbs, as illustrated in *Fig. 31*, were prepared for this purpose. In a globe *b*, was mounted a thin filament *f* (or button) upon a platinum wire *w* passing through a glass stem, and leading to the outside of the globe. The filament *f* was surrounded by a metal sieve *s*. It was found in experiments with such bulbs that a sieve with wide meshes apparently did not in the slightest degree affect

the bombardment against the globe *b*. When the vacuum was high, the shadow of the sieve was clearly projected against the globe, and the latter would get hot in a short while. In some bulbs the sieve *s* was connected to a platinum wire sealed in the glass. When this wire was connected to the other terminal of the induction coil (the E.M.F. being kept low in this case), or to an insulated plate, the bombardment against the outer globe *b* was diminished. By taking a sieve with fine meshes, the bombardment against the globe *b* was always diminished, but even then, if the exhaustion was carried very far, and when the potential of the transformer was very high, the globe *b* would be bombarded and heated quickly, though no shadow of the sieve was visible owing to the smallness of the meshes. But a glass tube, or other continuous body, mounted so as to surround the filament, did entirely cut off the bombardment, and for a while the outer globe *b* would remain perfectly cold. Of course, when the glass tube was sufficiently heated the bombardment against the outer globe could be noted at once. The experiments with these bulbs seemed to show that the speeds of the projected molecules, or particles, must be considerable (though quite insignificant when compared with that of light), otherwise it would be difficult to understand how they could traverse a fine metal sieve without being affected, unless it were found that such small particles, or atoms, cannot be acted upon directly at measurable distances. In regard to the speed of the projected atoms, Lord Kelvin has recently estimated it at about one kilometre a second, or thereabouts, in an ordinary Crookes bulb. As the potentials obtainable with a disruptive discharge coil are much higher than with ordinary coils, the speeds must, of course, be much greater when the bulbs are lighted from such a coil. Assuming the speed to be as high as five kilometres and uniform through the whole trajectory, as it should be in a very highly exhausted vessel, then if the alternate electrifications of the electrode would be of a frequency of 5,000,000, the greatest distance a particle could get away from the electrode would be one millimetre, and if it could be acted upon directly at that distance, the

exchange of electrode matter, or of the atoms, would be very slow, and there would be practically no bombardment against the bulb. This at least should be so, if the action of an electrode upon the atoms of the residual gas would be such as upon electrified bodies which we can perceive. A hot body enclosed in an exhausted bulb produces always atomic bombardment, but a hot body has no definite rhythm, for its molecules perform vibrations of all kinds.

If a bulb containing a button or filament, be exhausted as high as is possible with the greatest care and by the use of the best artifices, it is often observed that the discharge cannot, at first, break through, but after some time, probably in consequence of some changes within the bulb, the discharge finally passes through and the button is rendered incandescent. In fact, it appears that the higher the degree of exhaustion the easier is the incandescence produced. There seems to be no other cause to which the incandescence might be attributed in such case except to the bombardment, or similar action, of the residual gas, or of particles of matter in general. But if the bulb be exhausted with the greatest care can these play an important part? Assume the vacuum in the bulb to be tolerably perfect the great interest then centres in the question: Is the medium which pervades all space continuous or atomic? If atomic then the heating of a conducting button or filament in an exhausted vessel might be due largely to ether bombardment, and then the heating of a conductor in general through which currents of high frequency or high potential are passed must be modified by the behavior of such medium; then also the skin effect, the apparent increase of the ohmic resistance, etc., admit partially, at least, of a different explanation.

[*To be concluded.*]

THE CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting held Tuesday, October 17, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 17, 1893.

DR. D. K. TUTTLE, Vice-President, in the chair.

Dr. Wahl proposed the name of Mr. L. F. Kebler, chemist to Smith, Kline & French Company, manufacturing chemists, 305 Cherry Street, Philadelphia. The name was referred to the Committee on Admissions and Mr. Kebler was duly elected.

A letter from Miss Lizette A. Fisher to Dr. Wahl, announced the death of our fellow-member, Mr. R. A. Fisher, on October 6th. Dr. Tuttle appointed Mr. H. Pemberton, Jr., to prepare a suitable minute of the sad event.

Mr. Boyer suggested that such lectures of the Institute's general course, as were of special interest to chemists be made a part of the proceedings of the Section. Dr. Wahl stated that such a plan would be highly desirable, but its execution would be attended with serious expense to the Section, such expense being incidental to publication.

Dr. Wahl remarked, further on, the desirability of making the selection of lecturers on chemical topics, a duty of the Section. The president and others concurred in the views expressed by Dr. Wahl.

Dr. Hooker then read a paper "On the Azines of the Lapachol Group," and followed it with another on "The Change from Ortho- to Para- and from Para- to Ortho-Quinones." The papers were listened to with much interest, and were afterwards informally discussed by the author and Dr. Hall, Prof. Smith and Dr. Keiser. Beautifully crystallized specimens of the substances treated of were submitted for inspection.

A paper entitled "Experiments on Slag Cements," by Mr. R. W. Mahon was, in the absence of the author, read by title and referred for publication.

Adjourned. WM. C. DAY, *Secretary.*

THE DETERMINATION OF PHOSPHORIC ACID BY THE TITRATION OF THE YELLOW PRECIPITATE WITH STANDARD ALKALI.

BY HENRY PEMBERTON, JR.

[*Read at the stated meeting of the Chemical Section, held Sept. 19, 1893.*]

In the year 1882, I described a process for determining phosphoric acid, volumetrically, by ammonium molybdate, on the principle of Wildenstein's sulphuric acid determination, or of Gay Lussac's silver method. An *aqueous* solution of ammonium molybdate is run into the solution of the phosphate until no further precipitate is formed.

But it is not of this process that I now have to speak. It is referred to here, in order to draw attention to the concluding paragraph of the paper, as follows:

"I have obtained very sharp and accurate results by determining the amount of yellow precipitate (formed as above, after thorough washing), by means of a standard solution of caustic alkali, using litmus as an indicator; a description of which I hope to present in a future paper. I mention it here simply to place the fact on record." (*Journ. Frank. Inst.*, **113**, 193; *Chem. News*, **46**, 7.)

At that time I did a considerable amount of work upon the last-mentioned process, with very satisfactory results. A study was made of the conditions most favorable to obtaining a phospho-molybdate precipitate of constant composition, using solutions of di-sodic hydric phosphate of known strength, and also a solution of apatite, the determinations being checked by standard methods.

Before the process was in shape for publication, however, my attention was called to work of an entirely different nature, and no description of the method was published other than that embodied in the above-quoted paragraph.

Since that time several chemists have described processes based upon the same principle.

E. Thilo, in the analysis of Thomas slag (*Chem. Ztg.*, **11**, 193), dissolves the yellow precipitate in standard ammonia, and titrates back with acid, using litmus as an indicator.

Franz Hundeshagen (*Zeit. Anal. Chem.*, **28**, 171) uses standard sodium hydrate in excess, and titrates back with nitric acid, using phenolphthalein as an indicator.

C. E. Manby (*Jour. Anal. and Appd. Chem.*, **6**, 82) determines the phosphorus in steel, iron and iron ones, by dissolving the yellow precipitate in ammonia, acidifying with nitric acid, evaporating to dryness, and heating gently to expel nitric acid and ammonium nitrate. He then titrates, using the same solution and indicator as Hundeshagen employs.

James O. Handy (*Jour. Anal. and Appd. Chem.*, **6**, 204) avoids the evaporation and heating and titrates directly as Thilo and Hundeshagen do, using standard soda and phenolphthalein. M. Rothberg and W. A. Auchinvole (*Jour. Anal. and Appd. Chem.*, **6**, 243) also describe the same process.

Although it is now eleven years since I drew attention to this process, its advantages are so great that any information touching it, in addition to that furnished by the foregoing chemists, may be of interest. It far surpasses in quickness the process described by me (on the Gay Lussac or Wildenstein principle) and at the same time lacks nothing in accuracy. In most of the papers of the above-mentioned chemists, the process is applied to the determination of phosphorus in small quantities, as it occurs, for instance, in iron, steel or ores. During the past year, I have had occasion to apply it to the examination of a number of phosphate rocks, as well as of strong solutions of phosphoric acid, containing over fifty per cent. P_2O_5 and the method has been used continuously during that time. I am indebted to Mr. Edwin Harris, who had charge of most of the laboratory work of the factory, for many of the figures given below. It was seldom that two tests of the same material differed more than 0·1 per cent. in P_2O_5 even when the total P_2O_5 present amounted to as much as forty per cent. to fifty per cent. of the substance analyzed.

The following solutions are used:

Ammonium Molybdate.—Ninety grams of the crystals are dissolved (in a large beaker) in somewhat less than one litre of water. This is allowed to settle, overnight, and the clear liquor decanted into a litre flask. The small quantity of insoluble molybdic acid, always present, is dissolved in a little ammonia and added to the main solution. Should the molybdate be found to contain traces of P_2O_5, a few decigrams of magnesium sulphate are added, ammonia being added to faint alkalinity. The whole is then made up to one litre. It is this *aqueous* solution that is used, *no nitric acid whatever being employed.* Each cubic centimetre precipitates three milligrams of P_2O_5.

The *ammonium nitrate* solution is simply a saturated aqueous solution of the salt. Distilled water is poured into the bottle of crystals in quantity *in*sufficient to dissolve them all. Even in cold weather, ten cubic centimetres of this solution is amply sufficient for each test.

The *nitric acid*, used for acidifying the solution of the phosphate, has a specific gravity of 1·4, or thereabouts.

The *standard potassium hydrate* solution is of such strength that 1 cc. = 1 mgr. P_2O_5. One hundred cubic centimetres of it will neutralize 32·65 cubic centimetres of normal acid. It can be made from normal potassium hydrate (that has been freed from all carbonate, by barium hydrate), by diluting 326·5 cubic centimetres to one litre. But its strength is best determined empirically by a direct test upon a phosphate solution of known strength, precipitating with ammonic molybdate and making the analysis as described below, all carbonate of potassium having first been removed by barium hydrate.

The standard acid has the same strength, volume for volume, as the potassium hydrate, and can be made by diluting 326·5 cubic centimetres of normal acid to one litre. In testing it against the alkali, phenolphthalein (and not methyl orange) should be used.

The indicator can be either litmus, rosolic acid, or phenolphthalein. I have used the latter almost exclusively, as it has been shown, by J. H. Long (*Am. Chem. Jour.*, **11**, 84), that

titrations with this indicator in the presence of ammonium salts are perfectly reliable if the amount of the ammonium salt present is not excessive, if the solution is cold, and if the phenolphthalein is used in sufficient quantity. One gram of the phenolphthalein is, accordingly, dissolved in 100 cubic centimetres of sixty per cent. alcohol, and at least 0·5 cubic centimetres of this solution is used for each titration. The washing of the ammonium phospho-molybdate is done by water. (Isbert and Stutzer, *Zeit. Anal. Chem.*, **26**, 584.) It may be of interest to quote from their results, since it is by some chemists thought necessary to wash with a neutral or acid solution of an ammonium salt. In all tests, as made by them, twenty-five cubic centimetres of the sodium phosphate solution were precipitated by ammonium molybdate and the phosphoric acid determined therefrom, as magnesium pyrophosphate in the usual manner.

When the yellow precipitate was washed with ammonium nitrate solution, there was obtained:

(1) 0·1943 gram P_2O_5 in 50 cc.
(2) 0·1948 gram P_2O_5 in 50 cc.

When washed with *water*, there was found:

(3) 0·1947 gram P_2O_5 in 50 cc.
(4) 0·1942 gram P_2O_5 in 50 cc.

In order to establish the fact more certainly, the precipitate was washed with unusually large quantities of water:

	cc. of water used in washing.	*P_2O_5 found.*
(5)	300	0·1947 in 50 cc.
(6)	400	0·1944 in 50 cc.
(7)	500	0·1948 in 50 cc.
(8)	1,000	0·1940 in 50 cc.

There is, accordingly, no danger of loss in washing the yellow precipitate with water.

The following is the method of performing the analysis:

One gram of the phosphate is dissolved in nitric acid, an excess of which can be used with impunity, and the solution filtered into a 250 cubic centimetre flask and made up to the mark. The solution can even be poured into the flask without filtering, since the presence of a little insoluble

matter does not interfere in the least with the titration. Moreover, since most phosphate rocks seldom contain over ten per cent. of insoluble matter, and as this has the specific gravity of at least 2, it occupies a volume of about 0·05 cubic centimetre, an amount so small that it may be neglected. (For instance, even in the case of a phosphate rock containing forty per cent. P_2O_5, the error is only 0·008 per cent. P_2O_5.)

After the clear solution has been poured off, it is well to treat the sand, etc., at the bottom of the beaker, with a cubic centimetre or so of hydrochloric acid, in the warmth, to insure complete solution.

It is not necessary to evaporate to dryness. Isbert and Stutzer have shown, in their paper, that when the yellow precipitate is washed with *water*, the soluble silica is removed, and that evaporation (to render the silica insoluble) is superfluous. Their results are corroborated by the test analysis that will be given below. In the event of its being desirable to remove silica by evaporation, for any purpose, the evaporation should be performed over a water-bath, or, if on an iron plate, with great care, since, otherwise, meta- or pyro-, phosphates are formed with results that are correspondingly low.

Twenty-five cubic centimetres of the solution (equal to 0·1 gram) are now taken for analysis. It may be thought, by some, that an analysis made upon so small a quantity of material as one decigram, and with a standard solution representing only one milligram per cubic centimetre, may be liable to errors that would not exist, when using larger quantities or stronger solutions. But it should be borne in mind that the accuracy of measurement with a twenty-five-cubic-centimetre pipette, is precisely the same, whether ten grams of the original substance are taken or only one gram. Any error in measuring with a pipette is, of course, entirely independent of the quantity in solution. In regard to the amount of material to be manipulated (filtered, washed, etc.) it will be remembered that the weight of the yellow precipitate is over twenty-eight times the weight of the P_2O_5 contained in it. Every milligram of

P_2O_5 is accordingly represented by more than twenty-eight milligrams of precipitate. The standard alkali, although representing only 0·001 gram per cubic centimetre is, in reality more than three times as strong as the decinormal solution generally employed. Of course, in the case of materials containing only ten to fifteen per cent. P_2O_5, as in fertilizers, two or three grams can be taken for analysis, if desired, instead of one gram.

Returning, therefore, to the method of the analysis, twenty-five cubic centimetres of the solution are measured out and delivered into a beaker holding not more than 100 to 125 cubic centimetres. A larger beaker requires unnecessary washing to remove the free acid in washing the yellow precipitate. The solution is neutralized with ammonia—until a precipitate just begins to form—and five cubic centimetres of nitric acid of specific gravity 1·4 added. Ten cubic centimetres of the ammonium nitrate solution are added, and the entire bulk of the solution made up to fifty to seventy-five cubic centimetres by adding water.

Heat is now applied and the solution brought to a full boil. It is then removed from the lamp, no more heat being applied and treated *at once*, with five cubic centimetres of the aqueous solution of ammonium molybdate, which is run into it from a five-cubic-centimetre volume pipette, the solution being stirred as the precipitate is added. The beaker is now allowed to rest quietly for about one minute, during which time the precipitate settles almost completely. The five-cubic-centimetre pipette is filled with the molybdate solution, and a part of its contents allowed to drop in, holding the beaker up to the light. If a formation of a yellow cloud takes place, it is at once perceptible, in which case the remainder of the pipettefull is run in, the solution stirred and allowed to settle. A third pipettefull is now added as before. Should it cause no further cloud, only about one-half of its contents is added, the remainder being run into the beaker into which the filtrate and washings from the yellow precipitate are to go. In the test analyses given below, it will be shown that even when *fifteen cubic centimetres in excess*, of the molybdate, were purposely used, over and above the

calculated amount, the results were accurate—no molybdic acid coming down with the yellow precipitate.

It is seldom that more than fifteen cubic centimetres in all (three five-cubic-centimetre pipettefulls) of the molybdate have to be added. Since each cubic centimetre precipitates three milligrams P_2O_5, fifteen cubic centimetres will precipitate forty-five milligrams P_2O_5. This is equivalent to forty-five per cent. on the 0·1 gram taken for analysis, and it is not often that any material to be examined contains over this percentage. In the analysis of materials rich in phosphoric acid, it is one of the embarrassing features of the usual process, in which the *nitric acid solution* of the molybdate is used, that, in the first place, large quantities of the precipitant have to be used (frequently several hundred cubic centimetres), and, in the second place, that the analyst is never certain that enough has been added to throw down all of the phosphoric acid. This necessitates frequent testings of small portions of the phosphate solution, or of the filtrate. There is another difficulty peculiar to the process as usually carried out, in all methods in which the determination is made directly upon the phospho-molybdate itself, in that much care must be observed to keep the solution at a certain temperature, since otherwise molybdic acid contaminates the precipitate and the analysis is rendered worthless. In the process herein described, using an *aqueous* solution of the molybdate, the point at which sufficient of the precipitant has been added is easily seen. No molybdic acid separates, because, in the first place, no great excess of molybdate is added; and because, in the second place, the solution is filtered immediately, or as soon as it has settled, which requires only a minute or two. The time required from the first addition of the molybdate to the beginning of the filtration is never over ten minutes, and is generally less. The filtrate and washings from the precipitate when treated with additional molybdate solution, give, on standing on a hot plate for an hour or so, a snow-white precipitate of molybdic acid, showing that all of the phosphoric acid has been precipitated. I have observed this hundreds of times.

A slight correction should be made to the statement made above in regard to fifteen cubic centimetres of the molybdate precipitating forty-five milligrams of P_2O_5. This is not strictly true, for the reason that a small quantity (something over one cubic centimetre) of the molybdate is required to neutralize the solvent action of the nitric acid. Therefore, in *very* high grade phosphates a fourth five cubic centimetre pipette full may be required.

The yellow precipitate is now filtered through a filter seven centimetres in diameter, decanting the clear solution only. This is repeated three or four times, washing down the sides of the beaker, stirring up the precipitate, and washing the filter and sides of the funnel above the filter each time. The precipitate is then transferred to the filter and washed there. When the precipitate is large it cannot be churned up by the wash water and cannot be washed down to the apex of the filter. This is generally the case when there is over ten or fifteen per cent. phosphoric acid present in the substance analyzed. In such an event, I am accustomed to wash the precipitate back into the beaker, and to fill the funnel with water above the level of the filter, doing this two or three times, then washing the precipitate back into the filter. It is not necessary to transfer to the filter the precipitate adhering to the sides of the beaker.

It goes without saying that during the washing no ammonia must be present in the atmosphere of the laboratory. Inasmuch as the beaker, funnel, filter and precipitate are small, the washing does not take long to perform. It requires, in fact, from ten to fifteen minutes, even when large precipitates (= thirty to forty per cent. P_2O_5) are handled. The precipitate and filter are now transferred together to the beaker. By pressure with the tip of the finger, upon the double fold of the filter, it is easily given a sideways motion and lifted out of the funnel without any danger of breakage, the precipitate being still within it. The alkali solution is run in until the precipitate has dissolved, at least twelve drops of the phenolphthalein (1 : 100) are then added, and the acid run in without delay until the pearly color disappears and the solution is colorless. The presence of the

filter paper does not interfere in the least. The reaction of the indicator is not so sharp as when only acid and alkali are used, but it is easy to tell with certainty the difference caused by one drop of either acid or alkali. After deducting the volume of acid used from that of the alkali, the remainder gives the percentage of P_2O_5 directly, each cubic centimetre being equal to one per cent. P_2O_5. Thus, if there are 28·3 cubic centimetres of alkali consumed, the material contains 28·3 per cent. P_2O_5 when one decigram is taken for analysis. From the time the twenty-five cubic centimetres are measured out until the result is obtained, from thirty to forty minutes are required.

I have applied this process to determinations of phosphoric acid in phosphates and fertilizers, and have had no experience in determining phosphorus in iron, steel, or iron ores. I am inclined to believe that in the presence of such large quantities of iron salts when using the *aqueous* solution of the molybdate it may be necessary to guard against contamination of the yellow precipitate by ferric hydrate, perhaps by using larger quantities of nitric acid than five cubic centimetres, and perhaps by washing the precipitate at first, with dilute nitric acid. It may also be the case that the yellow precipitate will form more slowly.

The following analytical experiments were made in order to test the process.

Several phosphate of soda solutions were used at first, the strength of which was only approximately known, as the aim was to see how closely two readings would agree; equal quantities of the phosphate being taken for each pair of tests.

A.

	cc.
(1) KHO with rosolic acid, ...	15·0
(2) KHO with rosolic acid, ...	15·15

B.

	cc.
(1) KHO rosolic acid, ...	30·5
(2) KHO rosolic acid, ...	30·5
(3) KHO phenolphthalein, ...	30·7

All titrations, after this, were made with phenolphthalein.

C.

	cc.
(1) KHO, ...	31·7
(2) KHO, ...	31·8

A KHO solution was now made of such strength that 1 cc. = 1 mgr. P_2O_5.

D.

	mgr.
(1) P_2O_5, ...	50·35
(2) P_2O_5, ...	50·55
(3) P_2O_5, ...	50·40

E.

	mgr.
(1) P_2O_5, ...	51·6
(2) P_2O_5, ...	51·55

F.

	mgr.
(1) P_2O_5, ...	51·05
(2) P_2O_5, ...	50·95

D, E and F were solutions used in standardizing.

Two different samples of Florida phosphate rock were examined.

I.

	Per Cent.
(1) P_2O_5, ...	= 29·68
(2) P_2O_5, ...	= 29·84

II.

(1) P_2O_5, ...	= 31·28
(2) P_2O_5, ...	= 31·34

The following were solutions of phosphoric acid:

I.

	Per Cent.
(1) P_2O_5, ...	= 46·78
(2) P_2O_5, ...	= 46·69

II.

(1) P_2O_5, ...	= 44·41
(2) P_2O_5, ...	= 44·63

III.

(1) P_2O_5, ...	= 48·95
(2) P_2O_5, ...	= 48·80

The effect of *an excess* of ammonium molybdate was tried. The soluble part of an acid phosphate was made up to a definite volume and fifty cubic centimetres taken for analysis. It was found to contain 8·28 per cent. P_2O_5. The

test was repeated, using fifteen cubic centimetres of the molybdate more than was used in the first trial. Result = 8·36 per cent. P_2O_5 equal to a difference of 0·08 per cent.

The following tests show that it is not necessary to remove silicic acid, by evaporating to dryness before precipitating with the ammonic molybdate.

A sample of Florida phosphate rock contained:

	Per Cent.
(1) P_2O_5 silica removed,	31·21
(2) P_2O_5 silica not removed,	31·21

Another sample of the same rock was also tried:

Silica removed:	Per Cent.
(1) P_2O_5,	= 30·5
(2) P_2O_5,	= 30·7
Average P_2O_5,	= 30·6

Silica not removed:	Per Cent.
(1) P_2O_5,	30·6
(2) P_2O_5,	30·7
Average P_2O_5,	30·65

When silica is not removed the filtrate from the yellow precipitate has a yellow tinge.

The relation between the P_2O_5 in the precipitate and the potassium hydrate was established by determining the strength of a solution of disodic hydric phosphate by precipitation as the ammonium-magnesium salt, and also by testing it by this titration process. The phosphate of soda solution was *weighed* (not measured), and the magnesia precipitate, after filtering, was dissolved and reprecipitated with ammonia. (Gooch, *Am. Chem. Jour.*, **1**, 405.) The results are given in Table I, the last column giving the amounts of P_2O_5 obtained on a basis of ten grams of the solution:

TABLE I.

	Weight of Na_2HPO_4 Solution. Grams.	*Weight of $Mg_2P_2O_7$ Obtained. Grams.*	*Equal to P_2O_5. Grams.*	*Grams P_2O_5 in 10 Grams of Solution.*
I,	75·824	1·2471	0·7956	0·10494
II,	101·167	1·6637	1·0614	0·10492
III,	101·622	1·6733	1·0676	0·10505
Average,				0·10497

Therefore, ten grams of the solution contain 0·10497 gram P_2O_5.

Weighed portions of the same solution were now precipitated with molybdate and the precipitate titrated with alkali. The results are given in Table II, the last column of which gives the number of cubic centimetres of alkali equivalent to ten grams of the solution. The indicator was phenolphthalein:

TABLE II.

	Weight of $Na_2H.PO_4$ Solution. Grams.	*Number of cc. of KHO Sol. Required.*	*= Number of cc. KHO Sol. Required for 10 Grams Solution.*
I,	7·4975	79·05	= 105·4
II,	7·8255	82·40	= 105·3
Average,			= 105·35

It follows, therefore, that 105·35 cubic centimetres alkali = 0·10497 gram P_2O_5, therefore,

(1) 100 cubic centimetres alkali = 99·64 milligrams P_2O_5.

The HCl solution was now titrated against the alkali, using phenolphthalein as the indicator. 99·00 cubic centimetres alkali were found to equal 99·05 cubic centimetres acid.

The HCl was then standardized against pure sodium carbonate.

(With methyl orange, cold:)

(*a*) 1·1291 grams Na_2CO_3 = 65·45 cubic centimetres HCl

(With phenolphthalein, boiling:)

(*b*) 1·1934 grams Na_2CO_3 = 69·2 cubic centimetres HCl

Therefore, 100 cubic centimetres =

(*a*) 1725· milligrams Na_2CO_3
(*b*) 1725· milligrams Na_2CO_3

Since 99·00 alkali = 99·05 acid, it follows that:

(2) 100 cubic centimetres alkali = 1726 milligrams Na_2CO_3

It has already been shown by (1) that 100 cubic centimetres alkali = 99·64 milligrams P_2O_5. Therefore, combin-

ing (1) and (2) we obtain 99·64 milligrams P_2O_5 = 1726· milligrams Na_2CO_3.

Dividing each by its molecular weight, we have:

for P_2O_5, ... $\frac{99·64}{142·06}$ = ·7014

for Na_2CO_3, ... $\frac{1726}{106·1}$ = 16·27

Therefore $P_2O_5 : Na_2CO_3$ = 0·7014 : 16·27 = 1 : 23·2.

In other words, 23·2 molecules of Na_2CO_3 are required to neutralize the yellow precipitate containing one molecule P_2O_5.

The above figures are based upon the following atomic weights:

Mg, ...	= 24·3
O, ...	= 16
P, ...	= 31·03
Na, ...	= 23·05
C, ...	= 12

$Mg_2 P_2O_7$ = 63·80 per cent. P_2O_5.

There is some uncertainty as to the correct atomic weight of magnesium. If Mg = 24 (instead of 24·3 as taken above) with $Mg_2P_2O_7$ = 63·98 per cent. P_2O_5 the ratio of Na_2CO_3 to P_2O_5 = 23·1 to 1 (instead of 23·2 to 1). It is difficult to obtain *absolutely* pure Na_2CO_3; any impurity in it will make the ratio of Na_2CO_3 to P_2O_5 too high.

Practically, therefore, twenty-three molecules of Na_2CO_3 are required for one molecule P_2O_5. This agrees with Hundeshagen's results.

I have never seen any explanation as to why twenty-three molecules of alkali are required to neutralize one molecule of the ammonium-phospho-molybdate. A discussion of the subject, therefore, may be of interest. Hundeshagen has shown (*loc. cit.*) that (neglecting any water of crystallization) the yellow precipitate, after thorough washing with water, has the following composition:

$$\begin{array}{r} PO_4 \\ 12.MoO_3 \\ 3\,NH_4 \end{array}$$

Or, doubling the formula, for the sake of clearness:

$$\begin{array}{r} P_2O_8 \\ 24\ MoO_3 \\ 6\ NH_4 \end{array}$$

R. T. Thomson has shown in his researches on indicators (*Chem. News*, **47**, 127) that of the three hydrogen atoms in H_3PO_4 two must be saturated with alkali before the reaction with phenolphthalein will be neutral. The next drop of alkali after this causing the red color to appear. Writing the formula differently, $H_6P_2O_8$ must become $R_4H_2P_2O_8$ (R being the radical NH_4, or any alkali metal). Therefore, when the yellow precipitate is broken up by alkali, only four of the six molecules of NH_4 are required to form (with the P_2O_5 of the precipitate) a phosphate of ammonium that is neutral to the indicator. The remaining two molecules of NH_4 unite with one molecule of MoO_3, yielding also a salt that is of neutral reaction. This leaves twenty-three molecules of MoO_3, representing the "net available acidity" (if I may use the expression) of the ammonium-phosphomolybdate. These twenty-three molecules of MoO_3, of course require twenty-three molecules of Na_2CO_3 (or its equivalent of KHO) to form Na_2MoO_4. Q. E. D. The following is the formula representing the reaction:

$$\begin{array}{c} 6NH_4.\ P_2O_8.\ 24MoO_3 + \\ 23Na_2CO_3, + H2O, = (NH_4)_4.\ H_2P_2O_8 + \\ (NH_4)_2MoO_4 + 23Na_2MoO_4 + 23CO_2 \end{array}$$

It may be well to give a short *résumé* of this method. One gram of phosphate rock, or two or three grams of fertilizer are dissolved in nitric acid, and without evaporating to dryness diluted to 250 cubic centimetres. The solution need not be filtered. Twenty-five cubic centimetres of the solution are delivered into a four-ounce beaker and neutralized with ammonia—until a precipitate just begins to form—and then treated with five cubic centimetres of HNO_3 of 1·4 specific gravity. Ten cubic centimetres of a saturated solution of ammonium nitrate are added and the solution diluted to a volume of fifty to seventy-five cubic centimetres.

It is then brought to a full boil, removed from the lamp and five cubic centimetres of the *aqueous* solution of ammonium molybdate added. This is followed by a second and a third five cubic centimetres, if necessary, the precipitate allowed to settle, and filtered at once through a seven centimetre diameter filter. It is washed *thoroughly* with water by decantation and on the filter. The filter and precipitate are transferred bodily to the beaker. Standard alkali is then run in and at least 0·5 cubic centimetre of phenolphthalein (one per cent. solution) added, and then standard acid, until the color vanishes. Each cubic centimetre of alkali equals one milligram of phosphorus pentoxide.

THE METHODS OF TESTING FATS AND OILS.

BY DR. ERNEST MAILLIAU.
Director of the Government Testing Laboratory at Marseilles, France.

[*Read at a special meeting, held June 8, 1893.*]

Dr. WM. H. GREENE, President, in the chair.

Dr. MAILLIAU spoke as follows:

GENTLEMEN:

The French Government and the Regency of Tunis have taken the opportunity of the great American World's Fair to bestow upon us the honor to communicate to you by conference and by practical experiments the analytical methods which we use in France to recognize the purity of the fatty bodies. I hope that you will give us your kind indulgence and facilitate our modest efforts with the good-will which you have already shown to all our fellow-countrymen who have come to you with the disinterested object of strengthening the scientific bonds which unite the two republics.

If the French and Tunisan Governments have chosen me for their representative, it is only because I direct the ministerial laboratory of technical tests founded for the purpose of studying all the products of the colonies and Mediterranean district, and especially oils and fatty matters as well

as the different products which are connected with them, and that I have acquired some knowledge of the subject by long practice and continual investigations.

This is the only laboratory of its kind, and has been placed at Marseilles, the great seaport of France and port of entry for colonial products.

The difficulties of chemical analyses of fatty matters are greatly increased, not only by the slight differences which characterize the various glycerides, but also by the numerous cases of isomerism, and the phenomena of oxidation and fermentation which modify their molecular structures, by the resins and the essential oils which they contain, and also by the foreign matters which injuriously affect them, and the composition of which varies infinitely according to the nature of the soil from which the plant draws nourishment, by the method of extraction, age, and a thousand other causes needless to mention.

Since the methods of communication have been facilitated, and exchanges have become more numerous, the different markets of the world have been flooded with fatty matters presenting different characters though of the same nature as those to which industry and commerce have been accustomed.

We have been led to seek methods of analysis for oils not by their impurities, which vary according to their origin, but by the examination of their principal constituents which remain practically the same for the same species.

For example, it is now well known, and we state with pleasure, since we have made the first of these observations, that the olive oil of Tunis, Morocco and other provinces often present the character of adulterated oils if analyzed without proper precautions, or by old processes.

Accordingly, the greater number of governments and large companies have been obliged to modify their specifications to control the purchases necessitated by their wants by methods better adapted to the needs of commerce and the progress of science. Accordingly, before trying the action of chemical reagents upon this product so extremely variable and alterable, it is indispensable for obtaining precise

results to submit the material to a purification preceded and followed by a number of filtrations. By thus removing the impurities which when present alter the results, we bring back the fatty bodies of the same species to a type which is always practically the same. To reach this end we work sometimes by washing with hot distilled water, sometimes with strong or dilute alcohol, sometimes we refine the fatty matter by the use of caustic soda lye (containing ten per cent. sodium hydrate), employed in the proportion of ten per cent. of the fat. The emulsion is poured upon a saturated solution of sodium chlorid and by the action of gentle heat, the different parts separate and the clear oil holding in suspension insoluble particles of soap rises quickly to the surface.

It is well to note that fatty matter, even when neutral, as has been demonstrated, dissolves notable quantities of alcohol, which must be eliminated, if this method of washing has been employed. The process of the operation cannot be fixed definitely; it varies according to the nature of the impurities and the object of the research.

It is certain, for example, in determining the amount of volatile acids we must be content with the simple filtration, and that when examining the oils of the cruciferæ we must not use caustic soda which changes organic sulphur to a soluble sodium sulfid. Having finished the preliminary operations, we may, according to circumstances, operate directly on the neutral fat or the fatty acids prepared from it.

The fatty acids collected in the nascent state (that is to say, when they rise to the surface in a pasty mass) have much stronger chemical affinities than when melted and de-hydrated. This difference is particularly remarkable in the examination of cotton-seed and sesame oils, the black and red colorations obtained very clearly with a mixture of five per cent. upon the nascent fatty acids are not visible with the same fatty acids when melted.

The purification skilfully made does not destroy the chemical characters of the oil, as is easy to verify, by treating comparatively the same oil containing five per cent. of

the fatty matter, the presence of which we wish to demonstrate. The reactions of the added material are in general intensified by these different treatments.

By working upon the fatty acids of the neutral oils, I have been able to demonstrate the purity of certain fatty matters which appeared adulterated and in which the presence of cotton-seed and sesame oils were indicated by the old methods which I have been able to revise.

(*Circulaire du Ministre de la Marine Française*, en date du 26 Juillet, 1892. *Rapport du Résident-général de Tunisie*, en date du 9 Mai, 1892. *Circulaires des Ministres du Commerce et de l'Agriculture*, etc.)

I well know that in practice these preliminary operations may appear very tedious, but I do not advise their use except in cases where adulterations have been indicated by the usual methods, and it is desired to make the proof positive.

Besides, I cannot understand why a chemist has always been expected in the analysis of such delicate materials as fats, to discover an infallible reagent, a single drop of which will immediately turn olive oil green, peanut black, sesame red, etc., so that any inexperienced person could discover adulteration and bring the perpetrator to justice. This requirement, of the most difficult part of verification, is absolutely incomprehensible and is only to be excused by the ignorance of those who ask it.

We will now proceed to the study of each oil in particular. We will pass rapidly over those which possess only a secondary interest, so as to lay greater stress upon those which are the object of a great number of sophistications, as for example, olive oil. But in the first place we will indicate rapidly the general processes, physical and chemical, which are used for the identification of the various fats.

GENERAL METHODS.

(1) *Specific Gravity.*—Specific gravity is taken with accuracy by the Mohr balance, which is too well known to need description. It must be borne in mind that the specific gravity of the same fat varies greatly with individual sam

ples, and this physical character is not sufficient to allow us to decide on purity or adulteration.

(2) *Action of Nitrous Fumes.*—We owe to a Marseilles gentleman, M. Poutet, the first serious proposition for recognizing certain adulterations of olive oil. It was designed especially to discover the presence of poppy-seed oil, with which at that time, olive oil was very frequently adulterated, and for which the process gave good results.

It is based upon the transformation of the olein to its isomeric modification elaidin, by the action of nitrous fumes. It has been modified by other chemists, Messrs. Boudet, Faure and Cailletet. The process of Mr. Cailletet was most sure and simple, and we use it in the following manner:

We take a tube 10 cubic centimeters long, $2\frac{5}{10}$ cubic centimetres wide, in which are twenty cubic centimeters of the fat to be analyzed. Six drops of pure sulfuric acid at 66° B. are added, the tube shaken one minute and then nine drops of nitric acid C. P. 40° B. are added, after which the tube is again shaken and then plunged in boiling water, where it is left exactly five minutes, after which it is cooled in a water-bath at 8° to 10° C., whence it is taken at the end of two hours, and the condition of the mass observed. It is well to note the different colorations obtained. First, after the addition of the sulfuric acid; second, after the addition of nitric acid; third, after the removal from the water-bath, and fourth after chilling.

(3) *Sulfuric Saponification.*—M. Maumené proposed to observe the rise of temperature produced by rapidly mixing sulfuric acid with oil. The manner of applying the process in our laboratory is as follows: fifty grams of the fat for analysis are weighed into a conical glass of 100 cubic centimeters capacity. The temperature is noted and ten cubic centimeters sulfuric acid, 66° B. at the same temperature as the oil, is added. The two liquids are stirred together for one minute. An accurate thermometer is then immersed in the upper portion of the mass, stirred slowly, and the maximum temperature noted. The initial temperature must be at least 20° C. In order to obtain exact results

it is well to make several determintions and take their mean, when the variation does not exceed 2° C.

To obtain the relative sulfuric saponification, we note the rise of temperature obtained with fifty grams of distilled water at the same temperature as the oil and ten cubic centimetres of the same sulfuric acid. The number of degrees obtained by the oil is multiplied by 100 and the product divided by the number of degrees obtained with water. This process has the advantage of giving results nearly constant with acids of somewhat different strength. I have tried the application of the sulfuric saponification with semi-solid vegetable oils, by working at 2° or 3° above their melting points, and the results have been very satisfactory, especially for palm-nut oil and cocoanut oil, because the differences between them and the fluid oils often amount to 45° or more, as, for example, between palm-nut oil and sesame oil.

(4) *Iodin Number.*—In the fatty bodies there are members of unsaturated series, as, for example, oleic acid, which can absorb into its molecule as many atoms of the halogens as there are lacking atoms of hydrogen for complete saturation. The iodin number of olive oil varies between 80 and 84, that of peanut oil is 97, while that of cotton-seed oil is 108. These differences then allow, within certain limits, the determination of the purity of the various fats. We apply the Hübl method as follows:

Solutions required :

Alcoholic solution of iodin, ...	50	grams.
Solution of hyposulfite of sodium, ...	24·8	grams per litre.
Solution of mercuric chlorid, ...	60	grams per litre.
Solution of potassium iodid, ...	100	grams per litre.

Five grams of fatty acid are weighed out, diluted to 100 cubic centimeters with alcohol ninety-two per cent.; ten cubic centimeters of the solution are taken and to it added twenty centimeters of the iodin solution and fifteen to twenty cubic centimeters of the solution of mercuric chlorid. The flask is closed and allowed to stand three hours. Twenty cubic centimeters of the potassium iodid solution

are added and the excess of iodin titrated. When the brown coloration begins to disappear a few drops of starch solution are added and then hyposulfite until color disappears.

We will pass in silence the other indices, such as that of acetyl, which is of use only to discover castor oil.

(5) *Freezing Point.*—The freezing point is easy to determine by means of a thermometer and a freezing mixture.

(6) *Melting Points of Fatty Acids.*—The dry and melted fatty acids are sucked into a capillary tube. After solidification the tube is placed beside the bulb of a sensitive thermometer and immersed in a beaker of water, the temperature of which is raised very slowly.

The reading of the thermometer is taken the instant the body passes from the solid to the liquid state.

(7) *Solidification Point of Fatty Acids* (*Titer.*)—The dried and melted fatty acids are placed in a tube 15 centimeters long and 2 centimeters in diameter, which is suspended in a wide-mouthed bottle with a perforated stopper. A thermometer graduated to tenths is inserted so that the bulb reaches the centre of the material. At the moment solidification commences a circular movement is given to the thermometer, stirring the whole mass; the thermometer is then left at rest and carefully watched till the mercury ceases to rise, the reading then taken gives the point of solidification, or titer, conventionally adopted.

(8) *Saturation.*—We operate on five grams of the melted and dried fatty acid with a solution of normal caustic soda. The number of cubic centimeters absorbed give the saturation number.

(9) *Solubility in Absolute Alcohol.*—We determine this in the following manner: the fat is neutralized by agitating in a closed separating funnel for thirty minutes with twice its weight ninety-five per cent. alcohol. After settling it is drawn off and the alcohol held in solution driven off at low temperature, after which it is agitated at 15° C., or at a few degrees above the melting point; or if solid at 15°, with twice its weight of absolute alcohol. A known quantity of this alcohol is evaporated, the residue weighed, and the quantity of oil dissolved by 1,000 grams of alcohol is calculated.

FLUID VEGETABLE OILS.

Olive Oil.—Olive oil, like other vegetable oils, is a mixture of neutral glycerids, olein, stearin, palmitin, etc., and a variable quantity of free fatty acids. It is the edible oil *par excellence*, and the south of France owes a portion of its prosperity to the cultivation of the olive tree. This culture is to-day almost precarious in certain countries, though the consumption continually increases and olive oil always enjoys the just title of uncontested superiority. We can only attribute these remarkable results to the adulterations made for the purpose of selling under the name of olive oil, seed oils, or adulterated olive oils. We would be easily freed from these adulterations if chemists had at their disposition absolutely sure means to recognize them. Unfortunately the similarity of composition and reaction of the various vegetable oils render the demonstration of their presence extremely difficult. In face of the prejudice caused by adulteration, the greatest efforts have been made to solve the problem, and although the results have not been sterile they have not yet reached a satisfactory solution. It is necessary to say that if certain adulterators succeed in selling seed oils disguised as olive, they reverse the problem for the chemist by making him seek olive oil in seed oil. I may remark that the fraud is not always so great, very often the proportion of seed oil is not higher than ten per cent. Consequently, for our methods of analysis to be considered absolutely good, they must give results without recourse to comparisons which are satisfactory to show five per cent. in a mixture. Under these conditions we will be certain to discover adulteration when made in the proportion of ten per cent.

Let us rapidly review the general processes for the recognition of arachide, sesame, cotton-seed and poppy oils in olive oil; and we must acknowledge that none of them demonstrate less than ten per cent.

Specific Gravity.—The specific gravity of olive oil varies from ·915 to ·918; we have ·917 to ·918 for undecorticated peanut; ·921 for decorticated peanut; ·923 for sesame; ·921 to ·924 for cotton-seed oil; ·924 for poppy oil. These

variations of density in the olive oil do not allow us to recognize a mixture with any degree of certainty.

Action of Nitrous Fumes.—When taken from the water-bath, if the oil contains a fairly large proportion of peanut oil, it will appear wine-red. Pure olive oil is, on the contrary, lemon-yellow. When taken from the cold bath a complete solidification is observed with pure olive oil, which has the appearance of very light fresh butter; with a mixture of fifteen per cent. of all other oils there is no solidification. This method gives good means of detecting peanut and poppy oils in edible oils, but is of less use when applied to oils used for industrial purposes, which may not solidify, though pure.

Sulfuric Saponification.—The rise of temperature of olive oil is 35°; the relative, 94°. A rise of temperature above 35° usually indicates adulteration, equal or lower results do not absolutely indicate purity, because certain pure olive oils give only 31°, 32° and 33°, and, in consequence, after the addition of seed oil, show only 34° to 35°.

Indices.—The iodin number varies from 80 to 85, and in a certain measure helps us to discover seed oils. It likewise offers us a quantitative method with a mixture of known oils. The variations in composition of the same oil vitiate its sensitiveness for determining mixtures from five to ten per cent.

We will not mention the other general processes, but will dwell particularly on the special reactions which characterize the presence of three oils most frequently used to adulterate olive oil, to-wit: peanut, sesame and cotton-seed.

These processes have a much greater analytical value than the general ones, for if in the course of analysis we find unsatisfactory results with the latter, we can detect adulterations with certainty by the former.

Examination for Peanut Oil.—The density is almost the same. The sulfuric saponification, and above all, the Cailletet process gives us good results, but only the presence of arachidic acid $C_{22}H_{44}O_3$ (melting point, 75°) allows the sure recognition of the presence of peanut oil.

We have adopted, with slight modifications, the method of Renard. Twenty grams of the oil are saponified by twenty cubic centimeters of a caustic soda solution of 36° B., diluted in 100 cubic centimeters, alcohol ninety per cent. The soap formed is precipitated by a fifty per cent. solution, in alcohol, of lead acetate which must be neutral. After complete precipitation, decant while warm, and wash the residue with alcohol, which after being ground in a mortar is agitated with 200 cubic centimeters of ether. This operation is repeated three times to remove the last traces of lead oleate soluble in ether. The residue is then put in a porcelain dish containing two or three liters of distilled water and fifty cubic centimeters hydrochloric acid. When decomposition is complete the solution is decanted and the fatty acids washed with distilled water, after which they are dried in an oven to remove the last traces of water, when they are dissolved in forty cubic centimeters of ninety per cent. alcohol. A drop of hydrochloric acid is added and the mixture chilled to 15°. Peanut oil gives a generous deposition of arachidic acid crystals. These are washed twice, using twenty cubic centimeters each time, of ninety per cent. alcohol, then three times with twenty cubic centimeters each time of seventy per cent. alcohol, in which arachidic acid is completely insoluble. The washing is complete when a few drops gives no residue on evaporation. The acids are warmed slightly and treated with boiling absolute alcohol. After filtration the alcohol is evaporated in the oven at 100°, till the weight of the residue remains constant. If the melting point of the residue is between 73° and 75° we can affirm the presence of peanut oil. We must be sure of the freedom of the fatty acids from all traces of oleic acid, which prevents their crystallization. This elaborate but truly scientific process must be carried out only by skilled hands.

Examination for Sesame Oil.—To recognize sesame oil in olive oil we can use the specific gravity, the sulfuric saponification and Cailletet process, but especially the method which we use in our laboratory, and which consists of the reaction of hydrochloric acid and sugar upon the fat.

We do not operate on the glycerid, but on the derived fatty acids. If the oil is operated on directly, we can obtain a red or pink coloration with a perfectly pure olive oil. I have frequently observed this coloration in my laboratory with olive oils from Tunis, Algiers, Molfetta, Bitonto (Italy), and more rarely with those from Provence. This coloration comes from the coloring matter dissolved in the juice which flows out along with the oil from the presses. This can be shown by treating the separated juice with hydrochloric acid and sugar, with which it gives a coloration exactly resembling that given by sesame oil. It is therefore of the highest importance to work with pure fatty acids, according to the process I am about to describe, and which has been called the Milliau process.

Method of Operating.—We saponify fifteen cubic centimeters of the fat under examination with ten cubic centimeters of the solution of caustic soda, 36° B., with the addition of ten cubic centimeters ninety-two per cent. alcohol. When the boiling mixture becomes clear we add 200 cubic centimeters hot distilled water and boil to expel the alcohol; then decompose with ten per cent. sulfuric acid. The fatty acids are removed from the surface in the pasty state and washed by shaking in a test tube with cold distilled water, after which they are heated in an oven to 105°. When the greater part of the water is eliminated and they commence to melt, we pour them on half their volume of pure hydrochloric acid, which has been saturated in the cold with finely pulverized sugar. The mixture is shaken violently in the test tube. The presence of sesame is always distinctly indicated by the rose or red coloration of the acid solution; other oils leave the acid colorless or communicate to it a slightly yellowish tinge.

This reaction is extremely delicate and permits the sure recognition of the presence of one per cent. of sesame oil not only in olive oil but in all fatty mixtures as well as in soap.

This process was presented before the Academy of Sciences by M. Debray, February 20, 1888, and was awarded the gold medal of the Société d'Encouragement. (Report

of M. Muntz, in the name of the Agricultural Committee, February 20, 1889.)

Examination for Cotton-seed Oil.—Until recently, the detection of cotton-seed in olive oil was considered impossible, and accordingly, the different scientific societies and several chambers of commerce promised great prizes to the inventor of a process which would detect this adulterant.

Two methods were proposed simultaneously—one by M. Bechi, the other by myself. These two proccesses, which at first sight appear quite analogous and based upon the same reaction, differ completely from the scientific standpoint as well as in the exactness of the results obtained. M. Bechi has based his process upon the direct action of silver nitrate upon the oils. As long ago as 1878, we made some experiments with M. Puget of a similar nature, and the uncertainty of the reactions led us to abandon them entirely.

M. Bechi's process possesses the serious inconvenience of causing us at times to reject as adulterated, oils which are absolutely pure, and thus work injustice and create a considerable prejudice against the firms which have sold them. From results obtained at the Institut National Agronomique of Paris, as well as in other laborotaries, a deep coloration has been found with oils absolutely pure. Outside of these inconveniences, which are sufficient to cause us to throw it aside, it has a defect of being based upon a coloration having no well-defined chemical character, and it produces effects with different substances, the action of which it is impossible to explain. The use of colza oil has the serious fault of bringing into the reaction a second oil which may be impure and completely vitiate the results. Finally, the conclusions reached by the Italian scientific commission, instituted at Rome by act of the ministry to study the Bechi process, show that it is not certain on quantities of less than fifteen per cent. It solves the problem of finding less than ten per cent. no better than the Cailletet process, which shows the presence of fifteen per cent. The same commission declared also that olive oil containing glycerin, free fatty acid, formic acid, acetic acids, does not give a sure

reaction with the Bechi reagent. Now, since all olive oils contain free fatty acid from several tenths of one per cent. for virgin oil to 100 per cent. in some industrial oils, what conclusions can we reach?

The Bechi process will give, from fifteen per cent. up, a brown coloration of variable intensity, but in oil containing cotton-seed oil, which is fresh and well refined, the only sort used for edible purposes, we have a very weak reaction; while with an olive oil perfectly pure, but containing organic or mineral matters in suspension or solution, which have an action upon the reagents, we should have a pronounced coloration.

That is why I gave up these uncertain and variable results obtained in 1878 and studied the action of the nitrate of silver not upon the oil itself but upon the products of saponification derived from it. The results obtained exceeded my expectations, and have been published by the press as the Milliau process.

[*To be concluded*]

The Electrical Section

OF THE

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 27, 1893.*]

Hall of the Franklin Institute,
Philadelphia, September 27, 1893

The stated meeting of the Electrical Section was called to order at 8.10 P.M. by President Willyoung, with twenty-one members and visitors present.

The minutes of the meeting of June 27th were read and approved.

The Treasurer reported a balance of $35.89 on hand, and presented bills for printing $3, and postage and mailing of notices $8.75, which were ordered paid.

A paper on "The Chloride Electrical Storage Battery," by Mr. Herbert Lloyd, was read by the author and discussed by Messrs. Hering, Spencer and Willyoung.

The meeting then adjourned. R. H. Laird, *Secretary.*

SOME INTERESTING PECULIARITIES OF THE ALTERNATING ARC LAMP.

BY THOMAS SPENCER.

[*Read at the meeting of the Electrical Section, held June 27, 1893.*]

Although arc lighting by means of direct currents has been practised in this country for nearly fifteen years, it is only quite recently that an attempt has been made here to utilize the alternating current for that purpose, although it is a historical fact that the very first attempts made to introduce arc lighting for street illumination was by means of such a current. I refer to the Joblochkoff candle. Joblochkoff found that he had to use an alternating current to make his two carbon pencils, which composed his candle, burn away equally. Since Joblochkoff's time there has been a great deal of work done in Europe, and especially in Germany, where greater progress has been made in the electrical sciences than any other part of the eastern continent, towards utilizing the alternating current for arc lighting, and I have the pleasure of showing you one of the latest productions of that country (both as to lamp and carbon to be used with it) this evening. The lamp itself, though, being an American production, it being manufactured by the Helios Electrical Company, of Philadelphia, under patents of the German company of the same name. This lamp I will speak of later.

As I said before, it is only quite recently that alternating currents have been utilized for arc lighting. The first systematical attempt of the sort was, no doubt, that of the pioneers of alternating currents in this country, the Westinghouse Electrical Company, of Pittsburgh, Pa., when they put upon the market their well-known alternating series system. This was, no doubt, brought about by a circumstance, and that circumstance was the invention by Mr. William Stanley, who was then consulting electrician for

that company, of a wonderful constant current alternating current dynamo. This machine I look upon as one of the most beautiful in its performance of anything in the whole range of electro-dynamic machinery. It was my pleasure to be so situated as to have the handling of two of the first machines of this kind sent out by the company, the performance of these machines were simply wonderful. I have time and time again switched one of these machines from full load; that is, sixty arc lamps, each taking forty-five volts, to a dead short circuit, with only a variation of a half ampère in the current, and this without any mechanical regulation. I would say, in passing, that with this machine the only thing to be feared was an open circuit, and that the safe way to run the machine was dead short circuited.

The principle on which this machine worked was very vaguely understood for some time, the inventor himself having a very complicated explanation, based on armature reaction, but no doubt the correct explanation is this: The machine has an armature of the tooth form, on which there is wound quite a large amount of wire, and as a result the electro-motive force generated by the machine is quite large, but on account of the way the armature is constructed there is a large self-induction. These two factors being so great the actual resistance in the current becomes insensible in comparison with them, so the current is practically independent of the resistance in circuit; or, in other words, constant.

This can more clearly be seen from the following equation:

Where

c, is the current.
E, the electro-motive force.
R, the total resistance in the circuit, including the resistance of the arcs of the arc lamps.
L, the coëfficient of self-induction.
$p = 2 \pi n$, where n is the frequency.

$$c = \frac{E}{\sqrt{R^2 + L^2 p^2}}$$

Now, if E and L are very large in comparison to $L\ R$, we have

$$c = \frac{E}{L\ p}$$

or the current is constant, no matter what the external resistance may be, providing it is not too large.

With such a machine the Westinghouse Company thought they had solved the problem of arc lighting by means of alternating currents, but in this they were mistaken ; in fact, this was really the easiest end of the problem, and although this machine has now been known for over three years, this system has made little progress, due to

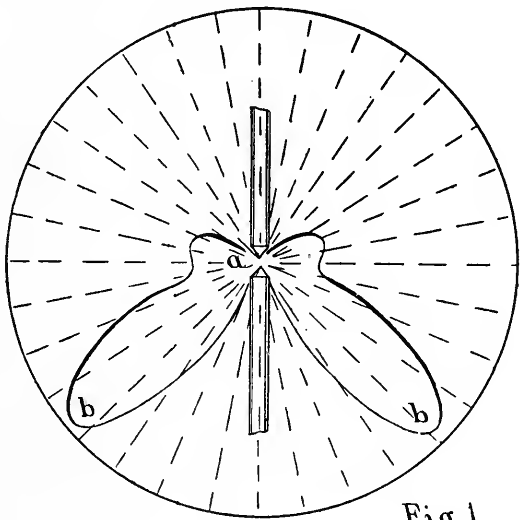


Fig. 1.

the fact that these lamps did not come up to the standard set by the direct system in common use.

The fact is, that here in this country an alternating current arc lamp has been studied entirely in those lines on which a direct current lamp was found to give the best results, while European practice shows plainly that a treatment entirely different should be followed.

Let us study the arcs formed by the two kinds of currents; first, as regards the distribution of their illuminating power.

Let *Fig. 1* represent the two carbon pencils in a direct arc lamp, where the upper pencil is supposed to be positive. Suppose we take a, the arc, as a centre of a circle,

and suppose we plot off on each radii the candle-power in the direction represented by it. Now, if we trace a curve through all the points thus found, we have a curve, as shown in *Fig. 1*, from which we see that nearly all the light is thrown down in the direction *a b*. This is due to the fact that nearly all the light from an arc lamp comes from the crater on the positive carbon.

Fig. 2 shows the curve for an alternating arc, which you see is altogether different from the first curve, there being four wings instead of two, as in the first curve, and these wings are shorter.

This distribution of light, of the alternating arc, has

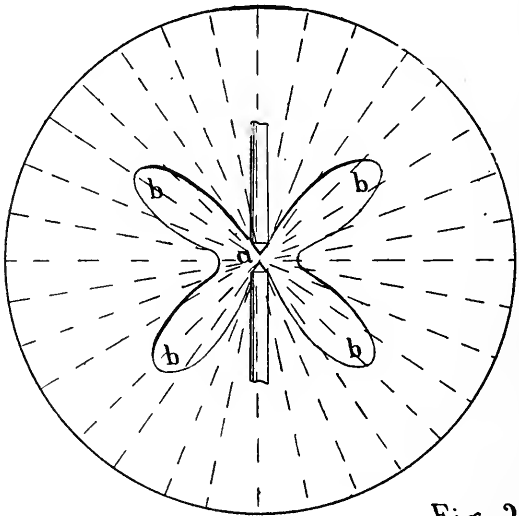


Fig. 2.

always been looked upon as a failing, for the light represented by the two upper wings is usually thrown up and wasted, especially if the lamp is out of doors. This defect has been in a great measure remedied in the lamp before you, by making the lamp focusing; that is, making the arc remain always in the same place, and using a white reflecting plate close above the arc. This plate will reflect something like eighty per cent. of the light incidenced upon it. There is another point in which there is a great difference in the two currents, it is this: One of the first things noticed about the alternating current, was that there was very little arcing at switches where currents of large ampèrage were broken. This pecu-

liarity was looked upon as a particularly valuable feature for, in the construction switches, the arcing was the principal thing to be guarded against, especially where high voltages were to be broken. I think, with the general introduction of alternating current plants, this property is not appreciated. One has only to stand and watch the arc that follows a plug switch in a direct arc switch-board, where the voltage is not over 2,500 volts and ten ampères, and to imagine what the result would be if the alternating current should suddenly acquire the same property, on some of the beautiful switch-boards for incandescent lighting of about the same voltage and much larger ampèrage, when the switches began to be thrown. There has been a great many theories about this property of the alternating current, but it is about settled that it is due to the fact that at a certain instant there is no current flowing to keep up the temperature of the vapor through which the current is flowing, sufficient to maintain a strong, hardy arc, and as a result it is easily broken. Now, this property, although it is just the thing we want, as far as switches are concerned, is far from desirable when we come to use the alternating current for arc lighting. It is evident from what has been said that an alternating arc is much less hardy than that of a direct current, of the same current density. We see, therefore, that it is a mistake to follow the lines of the direct system in devising an alternating system. What is desired is to get as much heat generated as possible in the flame, so as to keep up the temperature of the vapor through the time when the generation of heat practically stops for the instant. This is best illustrated by *Fig. 3*, where *a a a* is the current curve and *f f f* the temperature curve of the flame for the same instants, and *c c c* the minimum temperatures, which the flame reaches. Now *c c c* will be larger the larger the current, and the arc will be more hardy.

So it would seem that the only way to produce a good alternating arc lamp, is to use a large current, but a large current means a large candle-power, unless we lower what is called the counter electro-motive force of the arc, or the

drop in electro-motive force which occurs at the crater itself. If we refer to *Fig. 4*, where *A* and *B* are the carbon points, the distance between them being exaggerated for convenience, and suppose the drop in potential plotted from one point to the other, assuming *A* the positive carbon, we find for the direct system, at the point *a*; that is, at the crater, that there is a sudden drop of the potential to a point marked *b*. This drop is what is known as the counter electro-motive force of the arc. For the remaining part of the distance the drop is more gradual, and varies as the current. This is the part due to the drop in the flame itself. So it is apparent that if we could reduce the counter electro-motive force, leaving as large a loss of energy in the flame as possible, we would get an arc which would be much less affected

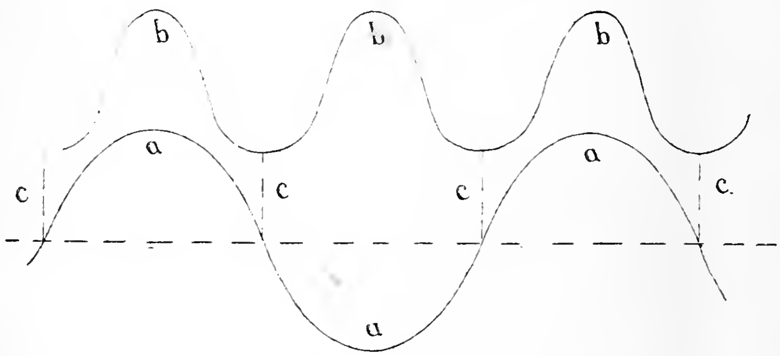


Fig. 3.

than with a smaller current, at the same time without any larger output in watts for the lamp. This has been done in the lamp before you by the use of a special low voltage carbon, which allows this lamp to give an illuminating effect with twenty-eight volts and ten ampères, equal about that given by a forty-five volt seven ampère direct-current lamp. Referring again to the counter electro-motive force, I would say that there has been a great deal of controversy over whether such a thing really existed. I myself am one of the party who believe in its existence. In fact, there is a strong current setting in the direction of that belief. I myself have been convinced that there was a real electro-motive force in the arc by studying the alternating arc itself; in fact, there are reactions in the arc which could only be

explained by the existence of a counter electro-motive force. A gentleman in England, whose name I have forgotten, has recently tried an experiment of heating a carbon juncture in a hydroxygen flame, and was able by this carbon thermopile to get quite a difference of potential between the two carbons. He claims that his results were such as to account for the counter electro-motive force of the carbons had been raised to the temperature of the arc. Also quite recently Sylvanus Thompson has tried quite a number of experiments bearing on this subject, and has come to the conclusion that the electro-motive force is the result of the energy which disappears as latent heat in the volatilization of the carbon in the crater.

There is another peculiarity of the alternating arc which is the most serious objection to it, from a commercial stand-

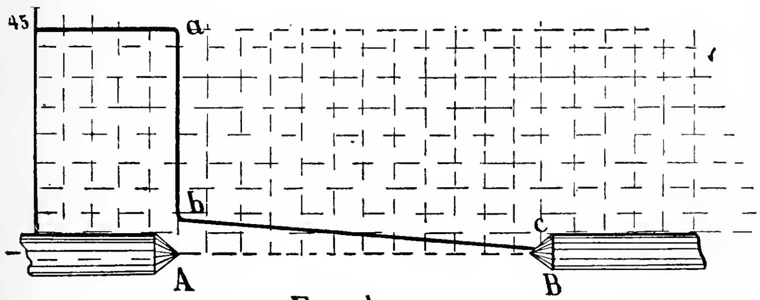


Fig. 4.

point, and that is the noise made by the arc. Even this has been attacked, and so overcome that it is no longer the objection it was in the early forms of lamps using alternating currents. The cause of this noise is due to the constant variation of temperature of the flame, as I have described already, which produces an expansion and contraction in the surrounding air. The result is a musical note depending on the frequency of the current. That there is a real rise and fall, even in the light given out by the arc, can be shown by moving a white stick, or better a short piece of white wire moved back and forth rapidly near the lamp, when the white band, caused by the persistence of impression in the eye, will be observed to be broken up into bands, showing that the light is varying with the alternations.

The noise is, I find, a function of the form of the current curve. This came under my notice in trying to substitute a choking coil in place of a resistance to absorb the excess electro-motive force above what was wanted at the arc. I noticed that the noise was considerably increased by the coil over the resistance. You can see that this is the case by the experiment I have arranged before you, which is so wired that either the resistance or coil can be used. You will observe that when the lamp is burning on the coil, there is considerable more noise than when the resistance is in circuit. The reason why this is the case will be explained by referring to *Fig. 5*, where let *a a a* be a simple curve of sines, which is very near the case, with a well-designed alternating dynamo. Let this curve be deformed

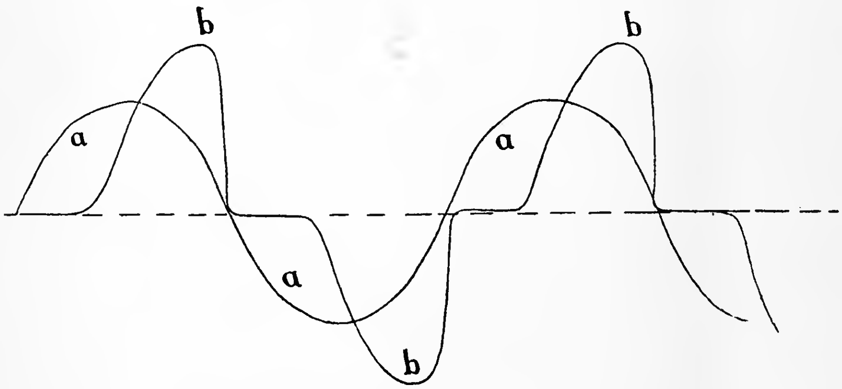


Fig. 5.

by the current represented by it, passing through a choking coil with iron. The deformed curve will be something like the curve *b b b*, due to the lack of constancy of the permeability, and to hysteresis in the iron. If we look at this curve we will notice an abrupt rise in it, which means a sudden rise of temperature in the flame; or, in other words, we would have a sort of explosion, and as a result this form of current curve would be more noisy. There is no doubt but the form of the current curve, which would be the best as far as sound is concerned, is that of the simple sine curve, for in this curve the current rises gradually, and sinks away gradually.

One thing which puzzled me for some time was that I found that a choking coil, which contained no iron, even

made more noise than when a resistance was used. As there was no changing permeability or hysteresis, in the arc, the cause for this increased noise was not quite so apparent. The explanation, no doubt, lies in the fact that no machine gives a true sine curve, but in most cases the curve is symmetrical as regards the rise, and fall, as will be seen by the curve *a a a*, *Fig. 6*, which is supposed to be the form of curve given by the dynamo. Now, a choking coil without iron would deform this curve to the form shown in the curve *b b b*, on account of the change of phases which it would bring about in the different harmonies which make up the compound wave coming from the dynamo.

It is found that when the frequency is reduced the noise is greatly decreased; for instance, lamps burned by means

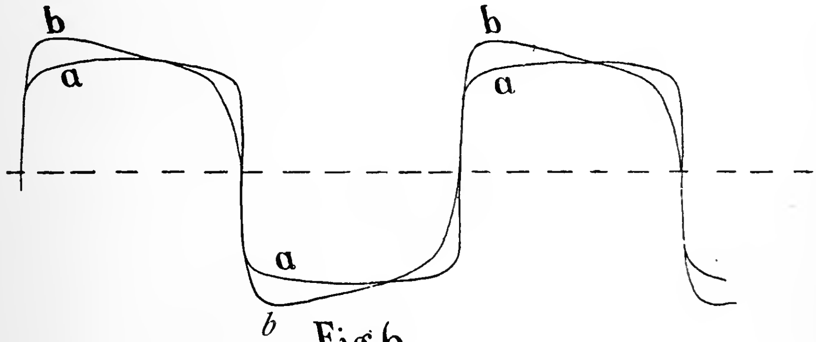


Fig. 6.

of the current supplied by some dynamos recently turned out by the Westinghouse Electric Company, which have a frequency of 7,200, practically made no noise. On the other hand, Mr. Tesla, by going the other way; that is, by raising the frequency above the audible point, made a perfectly quiet arc, but as high frequency introduced so many other objectionable features, I hardly expect to see this method very extensively introduced.

There is what you might call, still, a mechanical way by means of which the noise can, in a measure, be reduced, and that is by running with a short arc. The reason for this is self-evident, for by so doing you keep the flame well inside the hot walls of the carbon, which do not fluctuate as much in temperature as does the flame; as a consequence

the surrounding air is not so much affected, and the result less noise.

I will say in closing that an alternating arc lamp is something very much to be desired, as it forms one of the links in a chain towards which all electrical engineering is now drifting. I refer to the designing of a central station so that all kinds of electrical work can be done by one kind of current, which can be supplied by one kind of machinery at the central station. Not as now by several different kinds, as I saw to-day, a station using at least five different kinds of dynamos. That the alternating current is to be the current settled upon no one will deny, on account of its great flexibility. Therefore, I believe the alternating arc lamp has a great future before it, even greater than the series arc has had in the past. It, therefore, gives me pleasure to exhibit to you to-night a lamp, which I believe, embodies in its construction the most advanced idea in alternating arc light engineering.

BOOK NOTICES.

Electricity and Magnetism. Being a series of advanced primers of electricity. By Edwin J. Houston, A.M. New York: W. J. Johnston Company, 1893. 12°.

Electrical Measurements, and other advanced primers of electricity. By Edwin J. Houston, A.M. New York: W. J. Johnston Company. 1893. 12°.

The name of Professor Houston, recently elected President of the American Institute of Electrical Engineers, the highest honor within the gift of American electricians, is so widely known, not only as an eminent authority on electrical subjects but also as a scholar and author, that the intrinsic goodness of the above recently-published works might almost be assumed without investigation.

The two works noted above form part of a series of text-books which Professor Houston has in hand, and which are designed to simply and clearly elucidate the fundamental laws of electricity and the principal facts connected with its distribution and measurement. The first-named work is intended to bring out *principles* and *fundamental* facts rather than to have to do with *applications* of principles. Beginning with a brief historical retrospect the main phenomena of static electricity, the nature of insulators and conductors, the phenomena of electric discharges, the various dynamic, thermal and voltaic sources of electricity, are enteitainingly and instructively dealt with; following these chapters are others devoted briefly to electro-

receptive devices, *i. e.*, the motor, the arc and incandescent lamp, the storage battery, telephone, etc.; to a discussion of the *nature* of the electric current; to the system of units by which electricity is measured, etc. The various *kinds* of circuits, magnetism and the electro-magnet also receive full treatment.

The second work deals with applications rather than with laws; though entitled *Electrical Measurements* the larger portion of the work is devoted to a detailed consideration of the practical side of electricity with which the engineer and commercial electrician has principally to deal. The different kinds of voltaic cells are described and their advantages and disadvantages, with reference to different kinds of work mentioned; a brief mention is also made of the selenium and other better-known thermal cells. Following is an outline of the various systems of heavy electrical distribution, such as the Brush, Edison and Thomson-Houston systems; the series, multiple series, and other methods of coupling up receptive devices. Arc lighting is given a chapter by itself, as is also incandescent lighting. Alternating currents, as is right by virtue of their rapidly growing importance, receive an especially exhaustive treatment; the nature of the current; the construction of the alternating machine, etc., being clearly brought out; a separate chapter is devoted to the induction coil and transformer. This construction of dynamo machines and motors, including a discussion of the commutator and its function, the various methods of connecting armature sections, fields, etc., also receives full treatment.

An agreeable surprise in a work of this character is an interesting account of the work of Mr. Tesla, together with a discussion of the high-frequency phenomena in general. This alone should commend the book to students.

About seventy-five pages are given to the subject of "Electrical Measurements." Here the fundamental principles underlying measurements are explained. Measurements by means of the calorimeter and voltameter are discussed and a number of the necessary constants given. The sine, tangent and differential galvanometer are well explained, as also the electro-dynamometer, the construction of resistance boxes and the construction and method of use of the Wheatstone's bridge.

An admirable feature of both these books is the selection of pertinent quotations from standard works at the end of each chapter; these quotations are designed to interest the student in these more elaborate and exhaustive works. Another feature, which will be appreciated, is the summary of the entire work which is made in the last chapter; this is of great assistance in refreshing the memory.

These works are well bound and printed on good paper, in clear type. The illustrations are numerous and clear, though somewhat lacking from an artistic standpoint. The books are heartily commended to beginners as well as to electrical workers, who have had but small educational facilities, and desiring further knowledge; in them they will find much which will assist them in their daily work as well as a stimulus to further study.

E. G. W.

Practical Astronomy. By P. S. Michie and F. S. Harlow. Second Edition. New York: John Wiley & Sons. 1893.

Lord Bacon stated that mathematical science is the handmaid of natural philosophy. It is still more the handmaid of astronomy. And in this treatise on practical astronomy the authors have presented a book that describes the actual methods in use in an observatory, in field work, in explorations and in surveys. There has, of late years, been a superabundance of treatises on observational astronomy; treatises that, while valuable in their descriptive parts, make no pretension to being of service to the scientific working out of the various problems of astronomy. They are, in fact, intended for the star gazer, the *dilettante* and the general reader. The work before us, as stated in the preface, is designed especially for the use of cadets of the United States Military Academy. The usual methods of determining time, latitude and longitude, together with the requisite formulæ, are given. The construction of the ephemerides of the sun, moon and of a planet is explained, as are also the determination of azimuths and the projection of solar eclipses. The principal instruments in use are illustrated and their adjustments and uses described. P.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 18, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 18, 1893

JOSEPH M. WILSON, President, in the chair.

Present, eighty-four members and thirty-two visitors.

Additions to membership since last report, four.

Mr. Hexamer continued his remarks descriptive of the World's Columbian Exposition, illustrating the subject with a series of lantern views of buildings, grounds and interiors.

The Secretary's monthly report contained references to the present difficulties of the Nicaragua Canal Construction Company, the rapid growth of the electric railways in American cities, the extension of the applications of special steels for various constructive uses, etc, The Secretary also gave a further description of the process and machinery of the American Wire Glass Manufacturing Company, which had just started in operation an extensive plant at Tacony, Philadelphia. He also invited attention to a graphical chart prepared by the Geo. F. Blake Manufacturing Company, to illustrate the low efficiency of the present pumping engines supplying the city with water.

Adjourned. WM. H. WAHL, *Secretary.*

CHARLES A. COULOMB.

(1736—1806.)

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXVI. DECEMBER, 1893. No. 6

ON LIGHT AND OTHER HIGH FREQUENCY PHENOMENA.*

BY NIKOLA TESLA.

[*Concluded from p. 360.*]

It is certainly more nearly in accord with many phenomena observed with high frequency currents to hold that all space is pervaded by free atoms, than to assume that it is devoid of these, and dark and cold; for so it must be if filled with a continuous medium, since in such there can be neither heat nor light. Is then energy transmitted by independent carriers, or by the vibration of a continuous medium? This important question is as yet by no means positively answered. But most of the effects which are

* A lecture delivered before the Franklin Institute, at Philadelphia, February 24, 1893, and before the National Electric Light Association, at St. Louis, March 1, 1893.

here considered, especially the light effects, incandescence, or phosphorescence, involve the presence of free atoms and would be impossible without these.

In regard to the incandescence of a refractory button (or filament) in an exhausted receiver, which has been one of the subjects of this investigation, the chief precautions, to be observed in constructing such bulbs, may be summed up as follows:

(1) The button should be as small as possible, spherical, of a smooth or polished surface and of that refractory material which best withstands evaporation.

(2) The support of the button should be very thin, and screened by an aluminum and mica sheet, such as I have described on another occasion.

(3) The exhaustion of the bulb should be as high as possible.

(4) The frequency of the currents should be as high as practicable.

(5) The currents should be of a harmonic rise and fall, without sudden interruptions.

(6) The heat should be confined to the button by enclosing the same in a small bulb or otherwise.

(7) The space between the walls of the small bulb and the outer bulb should be highly exhausted.

Most of the considerations which we have just considered as applying to the incandescence of a solid may likewise be applied to phosphorescence. Indeed, in an exhausted vessel the phosphorescence is, as a rule, primarily excited by the powerful beating of the electrode stream of atoms against the phosphorescent body. Even in many cases where there is no evidence of such a bombardment, I think that phosphorescence is excited by violent impacts of atoms, which are not necessarily thrown off from the electrode but are inductively acted upon from the same through the medium or through chains of other atoms. That mechanical shocks play an important part in exciting phosphorescence in a bulb may be seen from the following experiment. If a bulb, constructed like that illustrated in *Fig. 10*, be exhausted as thoroughly as possible, so that the discharge

cannot pass, the filament f acts by electrostatic induction upon the tube t and the latter is set in vibration. If the tube o be rather wide, about an inch or so, the filament may be so powerfully vibrated that when it strikes the glass tube it excites phosporescence. The phosphorescence, however, ceases when the filament comes to rest. The vibration can be arrested and again started by varying the frequency of the currents. Obviously, the filament has its own period of vibration, and if the frequency of the currents is such that there is resonance, it is easily set vibrating, though the potential of the currents be small. I have often observed that the filament in the bulb is destroyed by such mechanical resonance. The filament vibrates, as a rule, so rapidly that it cannot be seen, and the experimenter may at first be mystified. When such an experiment as the one described is carefully performed, the potential of the currents may be extremely small, and for this reason I infer that the phosphorescence is then due to the mechanical shock of the filament against the glass, just as it is produced by striking a loaf of sugar with a knife. The mechanical shock produced by the projected atoms is easily noted when a bulb containing a button is grasped in the hand and the current turned on suddenly. I believe that a bulb could be shattered by observing the conditions of resonance.

In the experiment before cited, it may of course be said that the glass tube, upon coming into contact with the filament, retains upon the point of contact a charge of a certain sign. If now the filament again touches the glass on the same point while it is oppositely charged, the charges equalize, with an evolution of light. But nothing of importance would be gained by such an explanation. It is unquestionable that the initial charges given to the atoms or to the glass play some part in exciting phosphorescence. So, for instance, if a phosphorescent bulb be first excited by a high frequency coil, by connecting it to one of the terminals of the latter, and the degree of luminosity noted, and then the bulb be highly charged from a Holtz machine by attaching it preferably to the positive terminal of the machine,

it is found that when the bulb is again connected to the terminal of the high frequency coil, the phosphorescence is far more intense. On a previous occasion I considered the possibility of some phosphorescent phenomena in bulbs being produced by the incandescence of an infinitesimal layer on the surface of the phosphorescent body. Certainly, the impacts of the atoms are powerful enough to produce intense incandescence by their collisions, since they quickly bring to a high temperature a body of considerable bulk. If any such effect exists, then the best known appliance for producing phosphorescence in a bulb, is a disruptive discharge coil giving an enormous potential with but few fundamental discharges, say 25 to 30 per second, just enough to produce a continuous impression upon the eye. It is a fact that such a coil excites phosphorescence under almost any conditions and at all degrees of exhaustion, and I have observed effects which appear to be due to phosphorescence even at ordinary pressures of the atmosphere, when the potentials are extremely high. But if phosphorescent light is produced by the equalization of charges of electrified atoms (whatever this may mean ultimately), then the higher the frequency of the impulses or alternate electrifications, the more economical will be the light production. It is a long known and noteworthy fact that all the phosphorescent bodies are poor conductors of electricity and heat, and that all bodies cease to emit phosphorescent light when they are brought to a certain temperature. Conductors, on the contrary, do not possess this quality. There are but few exceptions to the rule. Carbon is one of them. Becquerel noted that carbon phosphoresces at a certain elevated temperature preceding the dark red. This phenomenon may easily be observed in bulbs provided with a rather large carbon electrode (say a sphere of six millimetres diameter). If the current be turned on after a few seconds, a snow-white film covers the electrode, just before it becomes dark red. Similar effects are noted with other conducting bodies, but probably not many scientific men will attribute them to true phosphorescence. Whether true incandescence has anything to do with phosphorescence

excited by atomic impact or mechanical shocks, still remains to be determined, but it is a fact that those conditions which tend to localize and increase the heating effect at the point of impact are almost invariably the most favorable for the production of phosphorescence. So, if the electrode be very small, in other words, if in general, the electric density is great, if the potential be high, and if the gas be highly rarefied (conditions implying high speed of the projected atoms, or matter, and consequently violent impacts), the phosphorescence is very intense. If a bulb provided with a large and a small electrode be attached to the terminal of an induction coil, the small electrode excites phosphorescence, while the large one may not do so, because of the smaller electric density and hence smaller speed of the atoms. A bulb provided with a large electrode may be grasped with the hand while the electrode is connected to the terminal of the coil and it may not phosphoresce, but if, instead of grasping the bulb with the hand, the same be touched with a pointed wire, the phosphorescence at once spreads through the bulb, because of the great density at the point of contact. With low frequencies it seems that gases of great atomic weight excite more intense phosphorescence than those of smaller weight, as for instance, hydrogen. With high frequencies the observations are not sufficiently reliable to justify a conclusion. Oxygen, as is well known, produces exceptionally strong effects, which may in part be due to chemical action. A bulb with hydrogen residue seems to be most easily excited. Those electrodes which are most easily deteriorated produce the most intense phosphorescence in bulbs, but the condition is not permanent because of the impairing of the vacuum and the deposition of the electrode matter upon the phosphorescent surfaces. Some liquids, as oils for instance, produce magnificent effects of phosphorescence (or fluorescence ?), but they last only a few seconds. So if a bulb have a trace of oil on the walls and the current is turned on, the phosphorescence only persists for a few moments until the oil is carried away. Of all bodies so far tried, sulphide of zinc seems to be the most susceptible to phosphorescence. Some samples obtained in Paris through the

kindness of Professor Henry were employed in many of these bulbs. One of the defects of this sulphide is, that it loses its quality of emitting light when brought to a very moderate temperature. It can, therefore, be used only for feeble intensities. An observation which might deserve notice is, that when violently bombarded from an aluminum electrode it assumes a black color, but singularly, it returns to the original condition when it cools down.

The most important fact arrived at in pursuing investigations in this direction is, that in all cases it is necessary, in order to excite phosphorescence with a minimum amount of energy, to bear in mind that no matter what may be the frequency of the currents, the degree of exhaustion and the character of the bodies in the bulb, there is always a certain potential (assuming the bulb excited from one terminal) or potential difference (assuming the bulb to be excited with both terminals) which produces the most economical result. If the potential be increased, considerable energy may be wasted without producing any more light, and if it be diminished, then again the light production is not as economical. The exact condition under which the best result is obtained seems to depend on many different circumstances, and the subject requires further investigation. In the meantime the required condition must be approximated as closely as possible in order to obtain the most favorable results.

Coming now to the most interesting of these phenomena, the incandescence or phosphorescence of gases, at low pressures or at the ordinary pressure of the atmosphere, we must seek the explanation of these phenomena in the same primary causes; that is, in shocks or impacts of the atoms. Just as molecules or atoms beating upon a solid body excite phosphorescence in the same or render it incandescent, so when colliding among themselves they produce similar phenomena. But this is a very insufficient explanation and concerns only the crude mechanism. Light, as is well-known, is produced by vibrations, of inconceivable rapidity. If we compute, from the energy contained in the form of known radiations in a definite space, the force which is

necessary to set up such rapid vibrations, we find that though the density of the ether is incomparably less than that of hydrogen or of any other known body, the force is something surpassing comprehension. What is this force, which, in mechanical measure, may amount to thousands of tons per square inch? In the light of modern views, we call it electrostatic force. It is impossible to conceive how a body of measurable dimensions could be charged to so high a potential that the force would be sufficient to produce these vibrations. Long before any such charge could be imparted to the body it would be shattered into atoms. The sun emits light and heat, and so does an ordinary flame or incandescent filament, but in neither of these can the force be accounted for if it be assumed that it is associated with the body as a whole. Only in one way may we account for it, namely, by identifying it with the atom. An atom is so small, that if it be charged by coming in contact with an electrified body and if the charge be assumed to follow the same law as in the case of bodies of measurable dimensions, it must retain a quantity of electricity capable of accounting for these forces and for these tremendous rates of vibration. But the atom behaves singularly in this respect; it always takes the same "charge."

It is very likely that resonant vibration plays a most important part in all manifestations of energy in nature. Throughout space all matter is vibrating, and all rates of vibration are represented, from the lowest musical note to the highest pitch of the chemical rays; hence, an atom, or a complex of atoms, no matter what its period, must find a vibration with which it is in resonance. When we consider the enormous rapidity of the light vibration, we realize the impossibility of producing such vibrations directly with any apparatus of measurable dimensions, and we are driven to the only possible economical means of electrically setting up waves of light, that is, by so affecting the molecules or atoms of a gas as to cause them to collide and vibrate. We must then ask ourselves, how can free molecules or atoms be thus affected?

That they can be affected by electrostatic force, is

apparent from many of these experiments. By varying the electrostatic force we can agitate the atoms and cause them to collide so as to evolve heat and light. It is not incontestably demonstrated that we can affect them otherwise. If a luminous discharge is produced in a closed exhausted tube, do the atoms arrange themselves in obedience to any other than electrostatic force acting in straight lines from atom to atom? Only recently I investigated the mutual action between two circuits with extreme rates of vibration. If a battery of a few jars (*cc*, *cc*, *Fig. 32*) be discharged through a primary *P* of low resistance (the connections being as illustrated in *Figs. 19a*, *19b* and *19c*), and if the frequency of vibration be many million, there are great differences of potential between points on the primary not

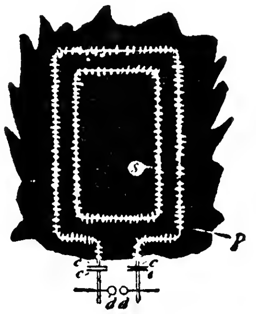


FIG. 32.—Electrostatic action between primary and secondary, with extremely high frequencies.

more than a few inches apart. These differences may be 10,000 volts per inch, if not more, taking the maximum value of the E.M.F. The secondary *s* is therefore acted upon by electrostatic induction, which is in such extreme cases of much greater importance than the electro-dynamic. To such sudden impulses the primary as well as the secondary are poor conductors, and therefore great differences of potential may be produced by electrostatic induction between adjacent points on the secondary. Sparks then may leap between the wires and streamers become visible in the dark if the light of the discharge through the spark gap *d d* be carefully excluded. If now we substitute a closed vacuum tube for the metallic secondary *s*, the differences of potential produced in the tube by electrostatic induction from

the primary are fully sufficient to excite portions of it; but as the points of certain differences of potential on the primary are not fixed, but are, generally, constantly changing in position, a luminous band is produced in the tube, apparently not touching the glass, as it should if the points of maximum and minimum differences of potential were fixed on the primary. I do not exclude the possibility of such a tube being excited by electro-dynamic induction only, for very able physicists hold this view; but, in my opinion, there is as yet no positive proof given that atoms of a gas in a closed tube may arrange themselves in chains under the action of an electro-motive impulse produced by electro-dynamic induction in the tube. I have been unable so far to produce striæ in a tube however long, and at whatever degree of exhaustion; that is, striæ at right angles to the supposed direction of the discharge or the axis of the tube, but I have distinctly observed in a large bulb, in which a wide luminous band was produced by passing a discharge of a battery through a wire surrounding the bulb, a circle of feeble luminosity between two luminous bands, one of which was more intense than the other. Furthermore, with my present experience of the subject, I do not think that such a gas discharge in a closed tube can vibrate as a whole. I am convinced that no discharge through a gas can vibrate. The atoms of a gas behave very curiously in respect to sudden electric impulses. The gas does not seem to possess any appreciable inertia to such impulses, for it is a fact, that the higher the frequency of the impulses, the greater the freedom with which the discharge passes through the gas. If the gas possesses no inertia it cannot vibrate, for some inertia is necessary for free vibration. I conclude from this that if a lightning discharge occurs between two clouds, there can be no oscillation, such as would be expected in view of the capacity of the clouds. But if the lightning discharge strike the earth, there is always vibration in the earth, but not in the cloud. In a gas discharge each atom vibrates at its own rate, but there is no vibration of the conducting gaseous mass as a whole. This is an important consideration in the great problem of producing light eco-

nomically, for it teaches us that to reach this result we must use impulses of very high frequency and necessarily also of high potential. It is a fact that oxygen produces a more intense light than hydrogen, in a tube. This is because oxygen atoms possess more inertia and the vibration does not die out instantly. But then nitrogen should be as good, as oxygen, while chlorine, and the vapors of many bodies should be much better unless the magnetic properties of oxygen come prominently into play. Or, is the process in the tube of an electrolytic nature? Many observations certainly indicate that it is, the most important of these being that matter is always carried away from the electrodes, so that the vacuum in a bulb cannot be permanently maintained. If such a process takes place in reality, then again must we have recourse to high frequencies, for, with such, electrolytic action should be reduced to a minimum, if not rendered entirely impossible. It is an undeniable fact that with very high frequencies, provided the impulses be of a

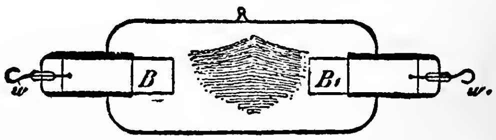


FIG. 33.—Carbon deposit in tube in a magnetic field.

harmonic nature, like those obtained from an alternator, there is less deterioration and the vacua are more permanent. With disruptive discharge coils, there are sudden rises of potential and the vacua are more quickly impaired, for the electrodes are deteriorated in a very short time. It was observed in some large tubes, which were provided with heavy carbon blocks B B_1, connected to platinum wires w w_1 (as illustrated in *Fig. 33*), and which were employed in experiments with the disruptive discharge instead of the ordinary air gap, that the carbon particles under the action of the powerful magnetic field in which the tube was placed, were deposited in regular fine lines in the middle of the tube, as illustrated. These lines were attributed to the deflection or distortion of the discharge by the magnetic field, but why the deposit occurred principally where the field was most intense did not appear quite clear. A fact of interest like-

wise noted was that the presence of a strong magnetic field increases the deterioration of the electrodes, probably by reason of the rapid interruptions it produces, whereby there is actually a higher E.M.F. maintained between the electrodes.

Much might be said about the luminous effects produced in gases at low or ordinary pressures. With the present experiences before us, we cannot say that the intimate nature of these charming phenomena is sufficiently

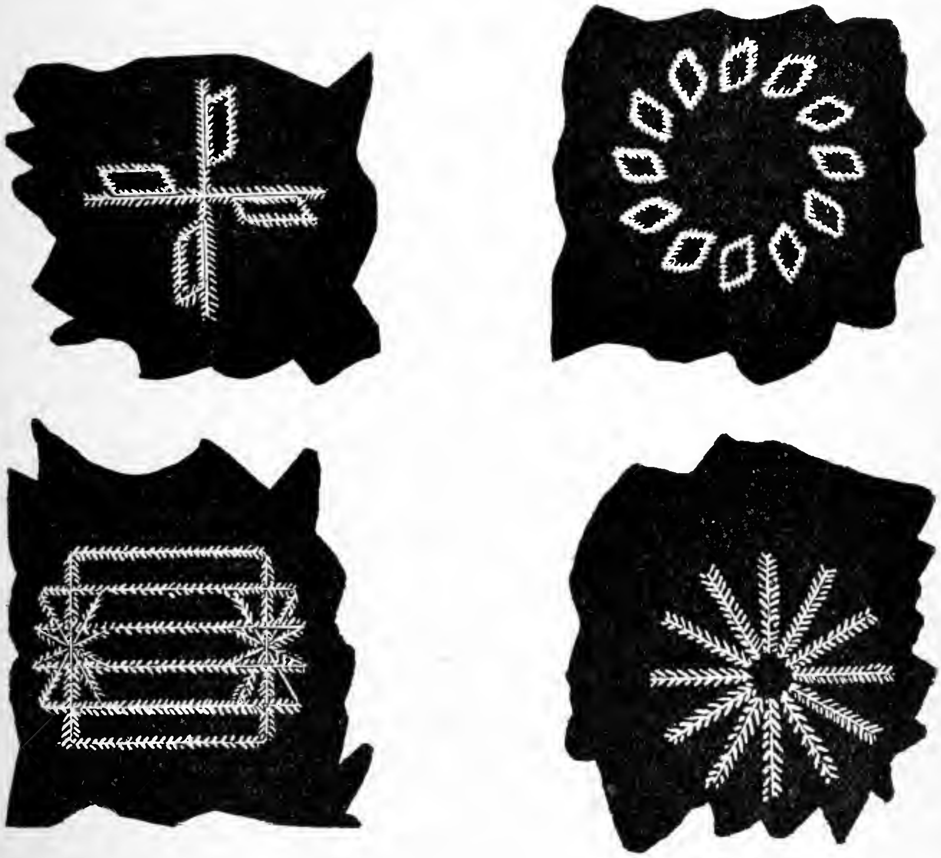


FIG. 34.—Spoke wheel, drum winding, alternate motor winding, ring winding. Some of the designs produced by intermittent discharges.

known. But investigations in this direction are being pushed with exceptional ardor. Every line of scientific pursuit has its fascinations, but electrical investigation appears to possess a peculiar attraction, for there is no experiment or observation of any kind in the dominion of this wonderful science which would not forcibly appeal to us. Yet to me it seems, that of all the many marvellous things we observe, a vacuum tube, when, excited by an

electric impulse from a distant source, it bursts forth, out of the darkness illuminating the room with its beautiful light, is as lovely a phenomenon as can greet our eyes. More interesting still it appears when, by reducing the fundamental discharges across the gap to a very small number and waving the tube about we produce all kinds of designs in luminous lines. So, by way of amusement, I take a long straight tube, or a square one, or a square attached to a straight tube, and by whirling them about in the hand I imitate the spokes of a wheel, a Gramme winding, a drum winding, an alternate current motor winding, etc. (*Fig 34.*) When seen from a distance the effect is weakened and much of its beauty is lost, but to one who sees the phenomenon close at hand it is irresistibly charming.

In presenting these insignificant results, I have not attempted to arrange and coördinate them as would be proper in a strictly scientific investigation in which every succeeding result should be a logical sequel of the preceding one, so that it might be guessed in advance by the careful reader or attentive listener. I have preferred to concentrate my energies chiefly upon advancing novel facts or ideas which might serve as suggestions to others, and this may serve as an excuse for the lack of harmony. The explanations of the phenomena have been given in good faith and in the spirit of a student prepared to find that they admit of a better interpretation. There can be no great harm in a student taking an erroneous view, but when great minds err, the world must dearly pay for their mistakes.

THE HISTORY AND MODERN DEVELOPMENT OF THE ART OF INTERCHANGEABLE CONSTRUCTION IN MECHANISM.

BY W. F. DURFEE.

I am to speak to you of the history and modern development of the art of interchangeable construction in mechanism.

This subject is so vast that it is impossible to treat it exhaustively in a single paper; nothing short of a copiously illustrated volume can convey an adequate understanding of the long, devious and weary way traversed by mankind in the journey towards the highest attainable perfection in handiwork, tools, machinery and their products.

The most that I hope to succeed in doing on this occasion, is to excite an interest in the history of the development of mechanical processes and apparatus, by brief notices of the more important inventions which, like milestones, mark the various stages of the road along which improvement has journeyed.

The study of the development of the mechanical adaptation of means to ends, is as essential to the thorough education of an engineer, as is a knowledge of biblical history, and of the lives of the fathers, to a theologian, or an acquaintance with Cæsar's commentaries and Jomini's Art of War to a soldier who aspires to command. Study of the laws of success is always assisted by an investigation of the causes of failure. Mechanical progress in the future can receive no more powerful acceleration than that furnished by a thorough knowledge of the laws underlying the successes and failures of past time.

That great Scotch-Englishman, Thomas Carlyle, tells us that: "Man is a tool-making animal; weak in himself, and of small stature, he stands on a basis, at most for the flattest-soled, of some half square foot, insecurely enough; has to straddle out his legs, lest the very wind supplant him.

Feeblest of bipeds! Three quintals are a crushing load for him; the steer of the meadow tosses him aloft like a waste rag. Nevertheless, he can make tools; can devise tools; with these the granite mountain melts into light dust before him; he kneads glowing iron as if it were soft paste; seas are his smooth highway, winds and fire his unvarying steeds; nowhere do we find him without tools; without tools he is nothing; with tools, he is all." Let us examine some of the work of this tool-devising and tool-using animal, and note his exercise of the creative power, with which he has been endowed, in the invention of tools and processes that enable the artisans of our day to produce those marvels of interchangeable mechanism which are the crowning glory of human skill in these closing years of the nineteenth century.

In looking backwards through the long perspective of the receding centuries for the first indication of an appreciation by man of the advantages of interchangeable construction, we recognize in the hands of the pioneers of the race, as they emerge from that "great deep" which, "without form and void," lies beyond the limits of authentic history, weapons and tools that possess the elements of interchangeability in as high a degree of development relatively to the knowledge of the times, as the most refined illustration of the art in our own day.

The bow of the primeval man had a sinewy string that would fit any other bow; his arrows were adapted to any bow-string; his paddle could be used in any canoe; the head of his spear would fit any shaft, and his uncouth hammer of stone, from the great interchangeable manufactory of nature, could drive a tent peg into the earth or a crush skull into fragments.

There is nothing improbable in the supposition that all the primitive arts originated in man's necessities and that a very general diffusion of a successful practice of those first essential processes was not only the explanation of their preservation but was the creator of wants more or less artificial. To satisfy these, other arts were devised, which in their turn led the way to more complex needs; one satisfied want

creating an unsatisfied desire, which inventive genius gratified.

Thus, step by step, through long ages past, mankind has progressed.

This slow engrafting of the artificial upon the natural man, has been noticed by many ancient writers. Virgil says:

> "Jove willed that man, by long experience taught,
> Should various arts invent by gradual thought."

Those who undertake to trace backward the development of civilization, cannot fail to note that all the more important inventions and discoveries have had, as a rule, more than one claimant. This rule has so frequently asserted itself, that it seems to justify the belief, that, when in the fulness of time, the world had become prepared for a decisive advance in the sciences or the arts, an overruling power indicated simultaneously to minds separated oftentimes by continents and oceans, some way to satisfy the growing needs of mankind.

Those whose prophetic minds are caused to see clearly, not only the scope of a pressing need, but also the means of satisfying it, we call discoverers and inventors; and such are deserving of honor and reward commensurate to the value of their services in the cause of human progress; but, unfortunately, they have too often been defrauded of a just recognition, and some paltry pilferer has been allowed to appropriate a recompense to which he had no righteous claim. A conspicuous instance of honor bestowed upon the undeserving, is furnished by the name of the Western World: Emerson tells us that Amerigo Vespucci, a "pickle dealer at Seville, who went out in 1499, a subaltern with Hojeda, and whose highest naval rank was boatswain's mate in an expedition that never sailed, managed in this lying world to supplant Columbus and baptize half the earth with his own dishonest name."

Names long established in geography and politics are not readily interchangeable, but, were it otherwise, one of the just results of this grand gathering of the nations on the soil of the continent discovered by Columbus, would be

the substitution of his name in all coming time for that of the "pickle dealer of Seville."

The term "interchangeable," as applied to mechanism, implies an ability to make a machine and all its component details exactly like a model; and if, in the making of a multitude of examples of a specific machine, the several details are made exactly like those of the model, it is obvious that any one of these details can take its appropriate place, and perform perfectly its allotted functions in any one of the machines.

In decorative art, what is sought is a systematic and pleasing adaptation of ornamental variety to the requirements of a particular object or situation, and uniformity of detail generally involves a sacrifice of artistic effect; but in the design of mechanism true art consists in the fitness of all the parts for their intended structural and functional purposes; and in the duplication of machines, conspicuous uniformity never advertises the poverty of art, but rather, by a satisfying sense of the "eternal fitness of things" mechanical, furnishes a material realization of true beauty, which has been defined as "the completeness of the whole, and the perfection of the parts."*

The more prevalent modern idea of the interchangeable in mechanism, supposes a super-refinement of accuracy of outline and general proportions that is not always necessary or even desirable. It would be a criminal waste of time and substance to fit a harrow tooth with mathematical accuracy, but yet any harrow tooth should have a practically interchangeable relation to all harrows for which it is designed. The instructive rewards of folly would certainly overtake him who should attempt to make "plow-shares" and "coulters" with radical exactness; nevertheless, these essential parts of plows should be interchangeable among all plows to which they are adapted.

It is fortunate that there is a recognized practical roughness of interchangeability, and that the refinements of agri-

* "True beauty consists in the completeness of the whole, and the perfection of the parts."—REV. THEODORE PARKER.

culture have not in our day reached the point which that great captain of romance, Lemuel Gulliver, tells us had been attained in the wonderful kingdom of Laputa, which he claimed to have discovered. This allusion to the common modern practice of making the parts of agricultural implements and mechanism roughly interchangeable, naturally calls to mind the earliest method of making the metallic parts of implements and apparatus in like manner—the art of casting.

This art has come down to us from a period of which history is ignorant, and from a people whose foot-prints have been obliterated by the dust and *débris* of countless centuries.

We shall never know who made the first crude casting or the circumstances attending its production. In that rude period, doubtless:

> "Th' invention all admir'd, and each how he
> To be th' inventor miss'd; so easy it seem'd,
> Once found, which yet unfound most would have thought
> Impossible!"

Few, if any, of the arts have had more potent influence than that of casting, upon the progress of humanity on its long journey from primitive barbarism to what each succeeding age, even to our own day, has complacently described as "modern civilization."

Whoever the discoverer of this art was, whether the Vulcan of Mythology or the Tubal Cain of the Scriptures, he is deserving of most honorable recognition; and if present civilization was disposed to be as just to its creators as that of ancient Greece, it would imitate its altars "to the unknown gods" by the erection of a monument of no mean proportions to the unknown inventors, who, by their discoveries, laid broad and deep the foundations of the arts of our time.

It is not germane to our purpose to dilate upon what has been accomplished by the art of casting among ancient peoples; examples of castings in brass and bronze, designed both for ornament and utility, abound in the museums of the world, but perhaps it may not be without interest, in considering the antiquity of casting in iron, to call your

attention to a matter of evidence that has not hitherto received much consideration.

It is well known that the heads of the battering machines used in ancient warfare were sometimes made of iron and shaped like the head of a ram; from this fact, and from the nature of its movement when in action, these machines were called battering-rams. The heads of these machines were exposed to a terribly destructive impact when in use, and therefore it is justifiable to suppose that they would have been made of a material easily shaped and from which duplicate heads could readily be supplied. Forged iron does not fulfil these conditions, for it was difficult to obtain in large masses at that time, and it is absurd to suppose that the ancients would have expended the time and labor necessary to carve a lump of wrought iron in the elaborately realistic way indicated by all the representations of battering-rams shown on ancient monuments. As it is certain that these "rams heads" were often made of iron, it appears to be more than probable that some tough variety of cast iron was used, in which case a new head could promptly take the place of a broken one, and the business of the siege go on without serious interruption.

Another evidence of the appreciation of the value of interchangeability of similar parts in ancient weapons of the heavier sort, is found in the gearing for twisting the funicular springs of catapults. This gearing is described by Rollin* as being made of cast brass or iron, but the Chevalier Folard† states that it was made of cast iron.

The origin of the catapult is uncertain, but it is believed to have been used by Nebuchadnezzar at the siege of Jerusalem and Tyre (588–586 B. C.)

Thus early did military engineers perceive the advantages of interchangeability among the more important similar metallic parts of machines of war; and thus early does cast iron appear as a material from which some of these parts were constructed.

---

* *The History of the Arts and Sciences of the Ancients.* By Mr. Rollin, 3 vol., London, 1768.

† *Histoire de Polybe*, Amsterdam, 1729.

Neglecting minor ancient examples of the interchangeability of parts produced by the art of casting, we come to the making of movable types.

This art is without doubt the most important exemplification of the grand results that have sprung from the original discovery that metals could be given any desired form by melting them and pouring them into moulds.

The printer's art rests firmly and solidly upon the art of casting; for the experience and skill of man for the past 450 years has utterly failed to find a satisfactory substitute for the art of casting by which to produce with requisite economy and precision the interchangeable type whose invention marks distinctly the beginning of a new era in the life of men upon the earth. As soon as movable types were invented, it became evident that extreme accuracy was essential in their production; in each variety of character in a "font" all types of the same letter must be alike both in "face" and "body," and the "bodies" of all type must be so related to each other, and to the "quads" and "spaces," that a given length of line can be perfectly filled. In the history of mechanical development nothing possible of attainment by ingenuity and handiwork has ever been asked of the artisans of the world that they did not immediately supply; and so this demand for a precision of execution unheard of before was met by workmen whose skill was quite equal, if not superior, to that of any of our time.

Some recent careful examinations and measurements of repetitions of the same word in "black letter" volumes about four centuries old, prove the correctness of the statement just made, for the agreement is quite as close as that noted in modern publications. In estimating the skill of the original type founders, we must not fail to remember that they were destitute of all those tools which are considered essential by modern skilled workmen for the production of accurate work in metal.

"Lathes," as then made, were crude and sporadic.

The "planing machine" was 300 years in the future, and the "shaping machine" fifty years more remote.

The "micrometer" was 180 years ahead of them.

The "milling machine" was far below their horizon of time.

The "black lead pencil" had not been invented; and the English unit of lineal measurement was a "barleycorn."

For the execution of good work, such as that required on the moulds for type, the type founder of those days was obliged to depend upon hammers, chisels, files, gravers, scrapers, grinding, the bow-drill, and burnishers; these were the tools which skilful hands and keen eyes then used in the shaping of metals.

While the originators and early practicers of the art of printing, who were also type founders, were successful in casting types that would interchange among those of the same founder; the types made by different founders would not interchange with each other, and it is to the credit of American artisans that they have perfected a system of manufacture by which it is quite possible to "make up" a "form of type" as large as the side of an ordinary newspaper, and, notwithstanding that the types may have come from half-a-dozen foundries, not a type will leave its place when the form is held horizontally by its "chase."

In recent years the art of casting type has been combined with the art of "composing" or assembling them into words and sentences. By means of exquisite mechanism actuated by power and controlled by keys properly fingered by the compositor, certain "letter matrices" are arranged in exact order at the bottom of a mould. Whenever a sufficient number of such matrices are assembled to form a line of predetermined length, melted type metal is forced into the mould, and as soon as it solidifies, the solid line of type (hence the name, "linotype," of the apparatus) is thrown out of the machine. This machine is a splendid example of the modern system of interchangeable construction, and for accuracy of workmanship and the perfect adaptation of means to ends, as well as for its rapidity of operation, it deserves to take rank among the wonders of human ingenuity.

The art of "stereotyping" is only an amplification of the art of casting single type, and to such perfection has the art

attained in some of the larger newspaper offices, that it is not unusual to make a *papier-maché* mould from the flat form of type, curve this mould to a proper radius, cast the "stereotype" from the mould, secure it to the cylinder of the fast press, and have the newsboys crying the n^{th} edition of the *Heraldic Tribune* and *Cosmopolitan Sun*, within twenty minutes after the arrival of the "form" in the stereotype room of the printing office.

For the invention of the art of printing, the world is indebted to Germany, and if that great nation,

> "Renowned for arts and arms,
> For manly talent and for female charms,"

had never made any other contribution to the commonwealth of knowledge, it would still be entitled to the grateful homage of mankind throughout the ages yet to be.

So noble an art as that of printing deserves the best that thought of brain and skill of hand can give. It has made the possibility and potentiality of knowledge the common heritage of all lands and peoples, and constituted itself the integrator and conservator of the science of the whole world.

Nations may rise or fall, dynasties may perish; but so long as man dominates the earth, the art of printing will be the educator of the succeeding generations, and will hand down from father to son, even unto the end of time, the ever accumulating wisdom of the rolling years.

For more than a century after the invention of printing, very little progress was made in mechanical invention. Feebly and with uncertain grasp the intellectual powers of man contended with the physical forces of nature; and all the world seemed to be awaiting the coming of some dominant genius like that of the great Sir Francis Bacon, through whom came such revelations of the force and scope of inductive reasoning, as changed the currents of civilized thought and conferred new powers and possibilities upon the mind of man.

From the time of Lord Bacon, human intelligence seemed to arouse itself from the torpor of past ages, and to assert.

by manifestation of a latent ingenuity and with an ever growing confidence, its creative power and supremacy over material things. This growing belief in the vast possibilities of the future, respecting discoveries in science and inventions in art, was quaintly expressed by Sir Hugh Platt, who, writing in 1595,* says: "That it is time, and high time, to let the world and all posterity to understand, that if our English artists (whereof sundrie in my knowledge are of such rare and singular conceipt, as they are, yea, and would also be found willing, if the stipend of honor and merit were now propounded, fully to discover a world of new inventions), they would bring forth so many, so rich, and so inestimable buds and blossoms of skill, as neither any civil policy that hath been hitherto shut up in printed books, nor any religious charity that hath been so often and so divinely sounded in at our deaf ears, could yet produce or show any comparable effects unto them." After briefly specifying a dozen inventions, for each of which large claims are made, Sir Hugh says: "I have always found it in mine own experience, an easier matter to devise many and very profitable inventions, than to dispose of one of them to the good of the author himself." In which conclusion, probably, most modern inventors will agree.

Among the first elements of mechanism to be made interchangeable by means of machine tools was the toothed gear wheel. An appreciation of the advantages of accuracy in the form of its teeth and of uniformity in their spacing was first decisively manifested by makers of clocks and watches.

A general idea of a wheel dividing and cutting machine was first suggested by Dr. Hooke, in the latter part of the seventeenth century, but the first tool of the kind acutally used is believed to have been made in France, and to have been similar to one described in Bion's work on mathematical instruments, published in 1702. The French were very much in advance of other nations in the invention of tools and appara-

---

* *A discoverie of certaine English wants, which are royally supplied in this treatise.* By H. Platt, of Lincoln's Inn, Esquire, printed at London by P. S. for William Ponsonby, 1595.

tus for the making of clocks and watches. In a work published in Paris in 1741,* there are detail engravings of three gear-cutting engines, two of which have perforated dial plates, and the third a worm-wheel and screw, for regulating the spacing of the teeth in the wheel being cut. The method of originating the divisions in the plates of these French machines is not described, but about the same period Henry Hindley (the inventor of the "hour-glass worm") a clock and watchmaker of York, England, constructed a machine for cutting gears which had a perforated dial plate. In a letter to John Smeaton (dated fourteenth of November, 1748), he explains the method of dividing the plate of this machine. This method involved the employment of a mechanical device, which, in the language of the workshops, we would now call a "jig,"† and Hindley is believed to have made the first

---

* *Traité de l'Horlogerie Méchanique et Pratique.* Par Thiout, Paris, 1741.

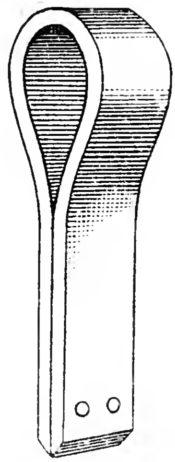
† *Tomlinson's Cyclopædia of Useful Arts.* Article, "Graduation."

Hindley's method was nothing more than an original, highly ingenious method of stepping. It is described in the letter referred to. The reason why it was not published until 1786 was, that Hindley entrusted it as a secret to Smeaton. He says: "First choose the largest number you want, and then choose a long plate of thin brass; mine was about one inch in breadth and eight feet in length, which I bent like a hoop for a hogshead, and soldered the ends together, and turned it of equal thickness upon a block of smooth-grained wood, upon my great lathe, in the air (that is, upon the end of the mandrel) one side of the hoop must be rather wider (thicker?) than the other, that it may fit the better to the block, which will be a short piece of a cone of large diameter; when the hoop was turned I took it off, cut and opened it straight again. The next step was to have a piece of steel bent in the form of per margin, which had two small holes in it of equal bigness, one to receive a small pin, and the other a drill of equal size. I ground the holes after they were hardened, to make them sound and smooth. The chaps formed by this steel plate were as near together as just to let the long plate through. Being open at the end,the chaps so formed would spring a little, and would press the long plate close by setting in the vice. Then I put the long plate to a right angle to the length of the steel chaps, and bored one hole through the long plate into which I put the small pin; then bored through the other hole, and by moving the steel chaps a hole forward, and putting in the pin in the last hole, I proceeded till I had divided the whole length of the plate. The next thing was to make this into a circle again. After the plate was cut off at the end of the intended number, I then proceeded to join the ends, which I did thus: I bored two narrow short brass

record of the use of such a tool. In the year 1783, an English mechanician by the name of Rehé, made a gear-cutting machine having a dial plate nineteen inches in diameter. Some of the cutters used in this machine were made of solid steel, and others had steel teeth inserted in a hub. The teeth of the cutters were shaped to give the proper profile to the teeth of the wheel being cut, and their general form is very suggestive of certain popular cutters used at the present time. As showing the estimation in which good machinery was held in England at the close of the eighteenth century, the fact that this machine was sold after the death of Mr. Rehé, for the sum of £700 may be of interest. As a companion to his gear-cutting, Mr. Rehé made a special machine for grinding and shaping its cutters. The work was done by revolving discs and cylinders of copper, fed with

---

plates as I did the long one, and put one on the inside and the other on the outside of the hoop, whose ends were brought together, and put two or three screw-pins, with flat heads and nuts to them, into each end which held them together till I riveted two little plates, one on each side of the narrow plate on the outside of the hoop. Then I took out the screws, and turned my block down till the hoop would fit close on, and by that means my right



line was made into an equal divided circle of what number I pleased. The engine plate was fixed on the face of the block, with a steel hole fixed before it, to bore through, and I had a point that would fall into the holes of the divided hoop, so by cutting shorter and turning the block less, I got all the numbers on my plate. I need not tell you that you get as many prime numbers as you please, nor that the distance of the holes in the chaps must be proportioned to the length of the hoop."

emery and oil. This "cutter grinder" is believed to have been the first of a race whose various representatives in our day are regarded as indispensable aids to the production of accurate interchangeable work.

In the year 1775, Jesse Ramsden completed in London the most ingenious and perfect piece of mechanism that, up to that date, had been produced for accurate reduplication—his dividing engine—by which circles within its capacity could be divided into any desired number of equal parts. This machine immediately occasioned important changes in the construction of nautical instruments, and furnished the means for increasing the accuracy of the perforated dial plates of wheel-cutting machines; in fact, the plate of Rehé's machine, already mentioned, was divided upon Ramsden's engine. Although in the best modern dividing engines an automatic feature has been incorporated, they are, in the general principles of their construction, but copies of the invention of Ramsden, which conferred new powers upon science and a greater refinement of skill upon the fingers of art.

The facility with which the cutters used in the various early gear-cutting machines, removed the metal in front of them when in operation, naturally suggested the employment of similar cutters for finishing flat surfaces, and the irregular outlines of a large variety of shapes in metal; but the progress of the idea was exceedingly slow, and in its development for general purposes mechanicians failed to study carefully the behavior of the cutters of that parent of all milling machines—the gear-cutting engine. This lack of careful reasoning from one use to another resulted in the fact that milling cutters, until very recent years, have been run utterly wrong with a degree of precision most wonderful in its results, but which is not especially creditable to the powers of observation and analysis of those responsible for doing so right a thing in so wrong a way. A boy whittling a stick should have been a good object lesson in this connection. The first milling machine for shaping the surface of metal of which we have any account, is illustrated in the French encyclopædia, the publication of which was completed

in 1772. This machine was designed for finishing the exterior of musket barrels, and, if properly managed, it could not fail to make every barrel of precisely the same shape. Milling machines were designed and used by Eli Whitney in the manufacture of muskets in the early years of the century, and James Nasmyth introduced the use of milling cutters ("rotary files," they were then called) into England in 1829, for finishing hexagon nuts, and later extended their use to other work. In America, the milling machine, in its various forms and adaptations, as manufactured by the Brown & Sharpe Manufacturing Company, the Brainard Milling Machine Company, the Pratt & Whitney Manufacturing Company, and many other makers of repute, executes a large proportion of the interchangeable work made. In the manufacture of fire-arms about forty per cent. of the machine tools used are some form of milling machines. Of one well-known and approved type of milling machine, known as the "Lincoln Miller" (originally designed by Mr. F. A. Pratt), or of substantial copies thereof, it is believed that at least 150,000 have been sold within the past thirty years.

Although the milling machine is perhaps more generally used for small work, in America than in any other country, yet we have been very slow to recognize its great value for the larger work for which it has been successfully employed abroad. Forty-five years ago there was built in England a milling machine for cutting out of the solid metal, and finishing at one operation, the inside cranks of locomotives. This machine had a cutting disc fifty-one inches in diameter, armed with inserted cutters moving at a circumferential speed of twenty-eight feet per minute with a forward feed of three and one-half inches per hour. The width of the cut was four inches, its thickness eleven inches, and its length, exclusive of the crank pin, fifteen inches. After the throat of the crank was cut out, the forward feed was stopped, and the shaft then given a rotation about the centre of the crank pin. The whole operation of cutting out the throat and finishing the pin was completed in nine and one-half hours. Notwithstanding the hints furnished

(certainly as early as the year 1702) by the use of circular revolving cutters for the purposes named, the mechanicians of the eighteenth century were many weary years in discovering that the same general ideas, so successfully used in metal cutting, could be made available in machinery for the working of wood; and it was not until the year 1777, seventy-five years after the first edition of M. Bion's work was published in France, and fifty-four after it had been translated into English,* that the first patent for the construction of circular saws for wood-working was issued. This patent was granted to Samuel Miller, of Southampton, England, on the fifth day of August, 1777. Among all the workers in wood at that time, there appears to have been no one able to transform the revolving cutter—that had been so long used for cutting metal—into the circular saw for the working of wood, and it was reserved for this Miller, a "sailmaker;" who by no conceivable accident ever used a saw of any kind in his handicraft, to invent what may fairly be regarded as the foundation of all the various rotary devices used in the manufacture of interchangeable articles of wood. In the year 1794, Sir Samuel Bentham, in association with his brother, the famous political economist, Jeremy Bentham, established at Queens Square Place, Westminster, the first manufactory of machines for the working of wood. These premises being soon found too small, No. 19 York Street was also occupied. The extent of the buildings justifies the inference that a large business was carried on. We are told by Professor Willis, in an address before the Society of Arts in 1852, that "there were constructed machines for all general operations in wood-work; including planing, moulding, rabbeting, grooving, mortising and sawing, both in coarse and fine work, in curved, winding and transverse directions, shaping wood in complicated forms, and that further, as an example, all parts of a highly-finished window-sash were prepared, also all the parts of an ornamental carriage wheel were made, so that

* *The Construction and Principal Uses of Mathematical Instruments.* Translated from the French of M. Bion, chief instrument maker to the French king, etc. By Edmund Stone, London, 1723.

nothing required to be done by hand but to put the component parts together." In 1797, the British Admiralty consented to the introduction of Sir Samuel Bentham's wood-working machinery into the dock-yards at Portsmouth and Plymouth. Machinery was made under the direction of Jeremy Bentham at the factory before-named. That the machinery made by Jeremy Bentham was thoroughly effective, was amply proved by evidence before a government commission, which awarded him £23,000 for the right to use it in the prisons and dock-yards of the kingdom.

The machines for the shaping of wood that were invented by Sir Samuel Bentham and carried into practice before the beginning of the present century, were very numerous and important; among them we find an improved rotary planing and moulding machine, a segmental circular saw, conical cutters for dovetailing, an undulating carriage for producing wave mouldings, cutter-heads for working two or more sides at once, tubular boring tools, cylinder saws (these, however, had been known as surgical instruments in the time of Hypocrates, 340 years B.C.), reciprocating and rotary mortising machines, bevel and curvilinear saws, rotary cutters for forming screw threads in wooden screws, and a large variety of other machinery for wood-working. In the year 1799, Sir Samuel Bentham recommended the adoption of the plans of Mark Isambard Brunel for the manufacture of ship blocks by machinery. The Admiralty authorized the construction of the machines, which were completed in 1806, and so efficient was their operation that the first year's saving was computed at £24,000, two-thirds of which was awarded to Brunel for the right to use his ingenious invention.

It has long been a popular belief that most, if not all, of the ideas involved in the construction of machinery for the manufacture of interchangeable constructions of wood, originated in America, but in view of the remarkable achievements of the Benthams and of Brunel, that opinion cannot be successfully defended, and we must take off our hats in acknowledgment of their great originality, and content ourselves with asserting that we have done mighty

work in developing the ideas we have inherited, and that America is the largest employer of wood-working machinery among the nations.

The lathe may safely be accounted the oldest of machine tools. Save that of the husbandmen, and of the tailor, and the art of lying, there is no art older than that of turning, for we are told that Adam and Eve were turned out of Eden, and the first turning tool ever mentioned in history is the flaming sword of the sentinel Cherubim which "turned every way."

It is certain that the "potter's wheel," doubtless the parent of all lathes, has been known from the earliest times. Potsherds are mentioned in the book of Job, and no ruins are so ancient that fragments of the work of the potter are not found therein. The transition from a rotation about a vertical axis, to revolution about a horizontal axis, and from shaping a soft mass of clay, with the fingers for turning tools, to the shaping of wood with a tool of iron or steel, seems to us at this day to be very simple and easy; but, judging from the exceedingly slow progress of the development of the art of wood-turning after its discovery, it is pretty safe to assume that several hundred years elapsed after the invention of the "potter's wheel" before anything like the rudest form of the wood-working lathe became known.

Diodorus Siculus attributes its invention to a nephew of Dædalus, named Talus, about 1240 B.C., but Pliny states that it was first used by Theodore of Samos about 740 B.C., and mentions one Thericles, who rendered himself famous by his dexterity in using it. The ancients employed it for turning a large variety of forms of vases, some of which they enriched with carvings. Centuries afterwards mankind began to perceive that the idea buried in the rotating mud of the "potter's wheel" could be still further expanded and made useful for the shaping of metals, and at this point in its history the lathe begins to assume importance as a contributor to the art of interchangeable construction.

In 1578, Jacob Bessoni published,* at Lyons, a remarkable

---

* *Theatrum Instrumentorum, Jacobi Bessoni Delphinatis, Mathematici Ingeniosissime.* Lugduni, Apud Barth Vincentini. Cum priveligio Regis. MDLXXVIII.

folio, containing sixty full-page copper-plates, illustrative of a variety of instruments and machines, among which are three engravings of lathes.

One of these contains a suggestion of a guide bar with a serpentine groove, and various holes designed to direct and assist in controlling the peculiar hand tool employed. This clumsy machine tool gives us a hint—somewhat feeble, it is true, but, still a reminder—that there was a feeling among the mechanicians of that day, that some machinery for turning irregular forms was desired, and that they had begun to grope around in the outer darkness where everything was unformed chaos, in the hope of discovering some means to satisfy that desire. Another of the plates in Bessoni's work, furnishes the first published suggestion for a screw-cutting lathe provided with a guide-screw, and the beginning of a slide rest, in means to solidly hold the cutting tool, while the screw being cut was moved longitudinally as it revolved in contact with it. The guide-screw, and in fact the whole structure of this lathe, is a crystallization of the uncouth, both in idea and in execution; but, nevertheless, it affords conclusive proof that there was a slowly developing demand for more exact work than had hitherto been possible, and that inventors were eneavoring to satisfy that demand.

The lathes described by Bessoni were all "dead-centre" lathes, and the work did not have a continuous rotation, but was alternately revolved by a cord, in a manner similar to a bow drill. This feature seems to have been common to all lathes prior to Bessoni's time. It seems strange that the economy of time, and the other advantages of a continuous rotation, as exemplified in the "potter's wheel," were not regarded by the makers of the early lathes.

The royal license and protection granted to Bessoni by Charles IX of France, for the publication of his invention, was really a royal patent for all the machines described, and, therefore, Bessoni's book may properly be regarded as the "drawings and specifications" of this early patent; which, if not the first, is certainly more comprehensive in its scope than any other ever granted to an inventor of machinery.

The announcement of the license of the king is such a curiosity of brevity and emphasis, that it is quite justifiable to quote it entire:

THE LICENSE OF THE KING.

By full and special license of the King, given to Master Jacques Bessoni, author of this present work, for ten years in the near future, dating from the day when the work is finished by the printer; all persons of whatever rank or condition they may be, are prohibited to make, counterfeit, engrave, sell or to consent thereto, even to the drawings for manufacturing the inventions contained in the present work, without the permission of its author. Upon the penalties contained and specified by said license. Given at Orleans in the year one thousand five hundred and sixty-nine on the twenty-seventh day of June. By the King in Counsel,

[SIGNED] BRULLART.

It may aid the comprehension of the relations of this work of Bessoni, to the science of the time, to know that when the above license was granted, Copernicus had been dead but twenty-five years. Tycho Brahe was but twenty-three years old, Galileo was in his fifth year, Elizabeth had reigned but ten years in England, and the Pilgrims were not to effect a landing on the "stern and rock-bound coast" of New England, until fifty-one years thereafter.

[*To be continued.*]

The Chemical Section

OF THE

Franklin Institute.

[*Proceedings of the stated meeting, held Tuesday, November 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 21, 1893.

WM. H. GREENE, President, in the chair.

The Treasurer called attention to a mistake that had been made in proposing for membership the name of Mr. J. Benjamin Glavin, after that gentleman had already been elected at a previous meeting.

Mr. Pemberton, as a committee of one to prepare a memorial of our late fellow-member, Mr. R. A. Fisher, read his report, which was accepted, with a vote of thanks from the Section. The report is herewith appended to these minutes.

A bill from the Actuary of the Institute for stationery and postage in sending out notices, etc., amounting to $10.99, was approved by the Finance Committee, and referred to the Treasurer for payment. A bill from the Secretary for postage, amounting to $2.60, covering a period of two years, was similarly recommended for payment.

The Actuary was requested to make a draft in favor of R. Friedländer & Son, for 173·25 marks, to cover subscriptions to current journals now due.

The nomination of officers for the year 1894 was then taken up. For President, Prof. E. F. Smith and Dr. Wm. H. Greene were nominated, but Dr. Greene declined the honor of a second term of office, thus leaving Professor Smith the only nominee.

Mr. H. Pemberton, Jr., and Dr. L. B. Hall were nominated for Vice-Presidents, and, on motion, it was voted that nominations for Vice-Presidents be closed.

The recent incumbents of the offices of Secretary, Treasurer and Conservator were re-nominated for their several offices, after which in each case it was voted that nominations be closed. Messrs. Hooker, Haines and Boyer were nominated for membership on the Committee of Admissions, the remaining members of this committee to be as usual the President, Secretary, Treasurer and Conservator.

Mr. L. F. Kebler presented a paper, entitled "Notes on the Examination of Beeswax." This paper, which showed much care on the part of the author, both in the experimental work involved and in the review of the literature of the subject, was well received, and was discussed by the President, Dr. Jayne and Mr. Haines. The paper was referred for publication in the *Journal.*

Dr. Terne read a communication from Mr. Williams, of Wilmington, in which the writer stated that he had tried the method proposed by Mr. Pemberton of determining phosphoric acid in fertilizer analysis, and found it entirely satisfactory. Dr. Terne also stated that the method had been used in his own laboratory with excellent results. Dr. Terne then read an exceedingly interesting paper on "The Availability of Nitrogen in Mixed Fertilizers." This was discussed by the President, Mr. Pemberton, Dr. Jayne and Mr. Haines, and was referred for publication.

The Section then adjourned. WM. C. DEY, *Secretary.*

THE METHODS OF TESTING FATS AND OILS.

BY DR. ERNEST MAILLIAU.
Director of the Government Testing Laboratory, at Marseilles, France.

[*Read at a special meeting, held June 8, 1893.*]

[*Concluded from p. 388.*]

Mailliau Process, Mode of Procedure.—In a porcelain dish of 250 cubic centimeters capacity, fifteen cubic centimeters of the oil to be investigated are heated to about 110°, then there is slowly poured on the oil a mixture of ten cubic centimeters of a solution of caustic soda of 36° B., and ten cubic centimeters of alcohol of 90° B. When the mass boils it becomes clear and homogeneous; 150 cubic centimeters of hot distilled water are added and boiling continued to expel the alcohol. The fatty acids are displaced with ten per cent. sulfuric acid solution added in slight excess, and the pasty acids immediately collected with a small platinum spoon. They are washed by shaking several times in a test tube with an equal volume of cold distilled water. The drops of water are drained off and they are then poured into a tube 2·5 centimeters in diameter and 9 centimeters long; fifteen cubic centimeters of alcohol ninety-five per cent. and two cubic centimeters of three per cent. nitrate of silver solution are added. The tube is protected from the light in the water-bath at 90° C. until about one-third of the alcohol is expelled, which is replaced by ten cubic centimeters distilled water. The heating is continued a few minutes and the coloration of the insoluble fatty acids is observed. *The presence of*

cotton-seed oil in any proportion whatever causes a mirror-like precipitate of metallic silver, which blackens the fatty acids of the mixture.

The members of the Agricultural Committee, composed of the greatest savants of France, MM. Pasteur, Eug. Tisserand, Boitel, Chatin, Heuge, Hardi, Rissler, Schloesing, Ronna, Lavaland, Muntz, Prillieux, Maret, Hon. Baron Thenard and Liebaut, after having tested the process on 128 samples from different provinces, have had the kindness to confer upon me the gold medal for this method of analysis, and I will take the liberty to present the conclusions of their Secretary, M. Muntz, director of the laboratories de l'Institut National Agronomique: "The preliminary saponification applied to the examination of fatty matters constitutes a new method on which we can confidently rely, not only in the analyses of edible products but also of those used for industrial purposes and also for soaps." (February, 1889.)

Before proceeding with this monograph, it is, of course, well understood that the same processes can be used for the detection of peanut, sesame and cotton-seed oils, in all other fatty mixtures.

Peanut Oil.—Peanut oil, apart from the arachidic acid which it contains, presents no special characters, as you can observe by examination of the chart upon which are indicated its physical and chemical properties.

Sesame Oil.—The purity of sesame oil may be demonstrated by shaking ten cubic centimeters of oil, first with five drops of sulfuric acid of 53° B., then with five drops of nitric acid of 28° B. The oil undergoes a progressive change of color through various shades from light green to red. The final red coloring matter obtained by this oxidation process turns yellow by the action of alkalies and returns to its original color with acids. This curious phenomenon does not take place with other oils but is obtained sometimes when working on sesame oils slightly adulterated; besides, the industrial oils from hot pressing, though pure, may give negative results. I have devised a rapid process, especially applicable for the recognition of castor oil in the industrial sesame oils.

Maillian Process.—For the rapid identification of castor oil and sesame, ten grams of the oil are shaken up with four drops of sulfuric acid of 66° B., a drop of nitric acid of 40° is added and shaken violently. Pure sesame oil blackens immediately, while that containing castor oil remains turbid yellow.

Cotton-seed Oil.—Concerning this oil, from a chemical standpoint, we have nothing particular to say. From the industrial point of view we may state that this product becomes more useful every day. Its cheapness allows everybody to use it, and this fatty material daily augments its important place in the markets of the world.

We will pass rapidly over the drying oils, poppy seed, linseed, walnut, cameline, over those of the cruciferæ, colza, rape and mustard, as well as the oils of the sweet almond, hazel nut and castor, the properties of which are shown upon the chart.

I will take the liberty, however, of mentioning a rapid process which I have devised for detecting the presence of castor oil in other oils. It is well known that the oils in general are soluble in petroleum ether, while castor oil, which distinguishes itself by its solubility in alcohol, is likewise remarkable for its insolubility in petroleum ether. Unfortunately this insolubility disappears at the ordinary temperature when a soluble oil is adulterated with a small proportion of castor oil.

It is only necessary to demonstrate its insolubility by shaking in a test tube one volume of the oil to be examined with two volumes of petroleum ether, and cooling the mixture to — 16° C. At the end of a few minutes the mass coagulates, and the oil separates if castor oil is present, while the liquid remains homogeneous if it is pure. This phenomenon is especially curious because it will be noted that the freezing point of castor oil unmixed with petroleum ether is much lower than that of most other oils.

SOLID VEGETABLE OILS.

Cocoanut and Palm Nut Oils.—The production of these oils, which is continually increasing on account of their

extensive use in the manufacture of soap during the last few years, has been made the object of several adulterations. Independently of the general chemical and physical character of these oils, as well as the sulfuric saponification which I have mentioned, we can employ with good results the determination of the saturation equivalent with normal caustic soda solution.

These oils, containing a greater amount of the lower fatty acids, require for their saturation a larger quantity of sodium oxide. To recognize these oils, it is only necessary to determine the number of cubic centimeters of normal solution required for the saturation of five grams of the pure fatty acid, viz: cocoanut oil, 24·1; palm nut oil, 22·5; while the average of the other liquid oils is seventeen to eighteen cubic centimeters only. This process presents some inconveniences, especially when trying to discover adulteration in small quantities, because it must be noted that the adulteration of these oils is practised only within certain limits, otherwise their appearance would lead to its detection. Besides, when an oil is made from old or spoiled seeds, the saturation is a little less.

Since the detection of adulterations in these oils depends on variations of a few tenths of a centimeter which might be caused by variations in quality of the oils themselves, or the method of operating, it is necessary to be very circumspect in the use of this truly scientific process.

With palm nut oil this error might be greater because it is customary to balance the low saturation of the seed oils by the addition of cocoanut oil. As, for example, five grams of fatty acids from a mixture containing forty-five per cent. of palm nut oil, forty-five per cent. cocoanut oil and ten per cent. peanut oil, require precisely 22·5 cubic centimeters normal solution for their saturation.

Iodin Number.—This determination is very useful because these oils, being very rich in saturated acids, absorb much smaller quantities of iodin than most other oils. For example, peanut gives ninety-seven, while cocoanut and palm nut show only nine to sixteen. Unfortunately, this difference of seven between the maximum and minimum,

throws us out of the way for small quantities of admixture, so much so that different authors fail to agree upon the average variation; some giving eight to nine only, while we are accustomed to find from thirteen to fifteen.

To recapitulate, this process, which if it gave constant results would be excellent, fails to give sufficiently accurate indications to detect adulteration of cocoanut oil when in small proportions. It is worse with palm nut oil and of no value to distinguish between the two.

Continuing our investigations in another direction we have fortunately found a process which gives constant results when used upon these oils after a preliminary neutralization.

We have discovered that cocoanut and palm nut oils are entirely soluble in absolute alcohol. At a temperature of 30° to 31° C., the former requires two volumes, and the latter four volumes, for complete solution.

It is a curious phenomenon that the smallest addition of vegetable or animal oils destroys this solubility in the same quantities of absolute alcohol. The solubility of the mixture is not proportional to its composition, but the mixture acts entirely like a distinct body.

Mode of Procedure.—First operation: Twenty cubic centimeters of the oil are shaken in a test tube with forty cubic centimeters of ninety-five per cent. alcohol. This indispensable preliminary treatment may give certain indications. Oil, soluble in ninety-five cent. alcohol, castor and rosin oil, etc., are thus discovered, while mowrah and karite oils give a milky turbidity to the alcoholic stratum.

Second operation: Five cubic centimeters of the neutralized cocoanut oil are measured with a pipette into a graduated test tube and ten cubic centimetres absolute alcohol added. The temperature is raised to 31°, the tube shaken violently for half a minute and then immersed in a water bath, kept at a temperature slightly above that of the tube.

Pure cocoanut oil dissolves completely and the solution remains clear. Any addition of another fatty matter causes precipitation; the material in solution being in a state of

molecular equilibrium, which is destroyed by the slightest modification.

Cocoanut oil containing palm nut oil precipitates when the proportion of the mixture amounts to twenty per cent.; below this the mass remains turbid.

The verification of palm nut oil is made in the same manner, only using twenty cubic centimeters absolute alcohol instead of ten, temperature remaining the same, 30° to 31°. Five cubic centimeters of palm nut oil containing twenty per cent. or more of cocoanut oil, dissolves in fifteen cubic centimeters of absolute alcohol. In the same proportions pure oil does not dissolve, and the mixture remains turbid.

A mixture of cocoanut, palm nut and peanut oils, in such proportions that the oil would appear pure by the indices of saturation, would easily be discovered by this process.

If we work at a lower temperature, the proportion of absolute alcohol must be increased. For example, at 25° to 26° it is necessary to double the quantity; for five cubic centimeters of cocoanut oil, use twenty cubic centimeters of alcohol, and for the palm nut forty cubic centimeters.

The same method may be used to determine the purity of cocoanut and palm nut cakes by first extracting the oil by means of a solvent and then operating on it in the manner described.

This process, which I have had the honor to describe, when carefully executed, enables us to determine in a few minutes adulterations of these oils which might cause bad results in soap making, which employs hundreds of millions of kilograms per annum, and in agriculture, which uses the cakes for cattle food. This process was presented to the Academy of Sciences, October 12, 1892, by M. L. Troost, and has been the subject of a favorable report to the Minister of Agriculture.

Let us pass rapidly over palm oil, of which the principal chemical properties are not remarkable except its partial solubility in absolute alcohol which is ten per cent. Also we will pass over the mowrah, which, as I have already mentioned, is identified by the milky white turbidity which it communicates to alcohol by shaking.

Illepi Oil.—This product, the titer of which is 52°·5, and cotton-seed margarine, or stearine as it is called here, whose chemical reactions are the same as the oil itself, will not long detain us.

While closing the description of the solid vegetable oils, I wish to mention karite oil, which comes from the French province, Soudan, which I have been especially directed to investigate by the Chamber of Commerce of Paris, and the Chamber of the syndicate for the manufacture of soap and candles.

It was very important for us to know how to utilize the great forest which covers the largest part of French Soudan. It is composed chiefly of the wild acacia and the karite or butter tree. The natives collect the nuts which fall from the trees, crush the kernels, treat the pasty mass with boiling water, and skim off the fat which comes to the surface. This fat, which is solid at the ordinary temperature, is used as an edible butter.

Without speaking about the great uses to civilization of this product, I must mention its remarkable chemical properties. The fatty acids, having a titer of 52°·5 C. combine with soda to produce an extremely hard soap. For candle making they would probably give better results, after preliminary treatment to remove the resinoid matters which they contain and which hinder the crystallization of the fatty acids.

The presence of these resins lowers the saturation to 14·9, and, like the mowrah, this oil causes turbidity by shaking with alcohol. (Communication of M. Mailliau to the Société d'Encouragement of Paris in 1892.)

SOLID ANIMAL FATS.

These are colored brown by a stream of chlorine gas.

Butter.—The analysis of this material, which has attracted so much attention during the last few years, is not so difficult as some imagine, but requires the skill of a practical and experienced analyst. The specific gravity of butter is notably lower than that of tallow and lard. It is the same with the iodin number and the freezing point of the

neutral fat. The saponification and the solubility in absolute alcohol on the contrary are notably higher.

We can further confirm our results by microscopical examinations; melted butters showing under the microscope a collection of small regular spheres. Adulterated butter shows, on the contrary, abnormal figures, as well as crystals, which appear brilliant in the dark field of the polarizer.

By determining the fixed and volatile fatty acids, and the point of solubility in alcoholic toluene, a skilled analyst familiar with these processes can easily determine admixtures above ten per cent. Below this point, I do not believe any adulteration would be profitable. Natural butter contains about eleven per cent. soluble and volatile fatty acids and eighty-seven per cent. fixed fatty acids. Besides, alcoholic toluene dissolves it almost entirely.

Tallow.—The properties of tallow are so well known that they require no description. The distinction between beef and mutton tallow is a matter of interest and presents great difficulties from the chemical standpoint, and we can observe differences only by taking the melting and solidifying points of the neutral fat and those of the fatty acids.

Lard.—Lard adulterated with cotton-seed oil is easily tested with nitrate of silver. If the lard has been altered by time or by other causes, it is necessary before using this reagent upon the fatty acids, to take the precaution of purifying the fat in the manner in which I have indicated at the beginning of this lecture. We will thus avoid the slight reduction which is produced by decomposition products.

Some authors strongly believe in the use of the iodin number, which will give good results in the case of large admixtures, as well as for quantitative analysis of such a mixture. But it is quite illusory for the detection of a small proportion of cotton-seed oil, for we must consider that the iodin number of pure lard varies within considerable limits, and it would be possible to correct for the high iodine number of cotton-seed oil by the addition of tallow, which will lower it appreciably. In such a mixture the action of nitrate of silver on the fatty acids enables us to discover adulteration even below five per cent.

A GENERAL COMPARATIVE TABLE FOR THE ANALYSIS OF FATTY MATTER.

		Fatty Substance.	1 Density at 15° C.	2 Action of Nitrous Vapors.	3 Sulfuric Saponification. Absolute.	3 Sulfuric Saponification. Relative.	4 Indices. Bromin.	4 Indices. Iodin.	4 Indices. Acetyl.	5 Freezing Points of Oils.	6 Fusing Points of Fatty Acids.	7 Solidification of Fatty Acids.	8 Saturation by Na_2O. Number of Cubic Centimeters of Normal Liquid Absorbed by Five grs. of Fatty Acid.	9 Solubility in Absolute Alcohol. Number of Grams of Neutral Oil Dissolved by 1,000 Grams Alcohol.	10 Deviation of the Plane of Polarization.	Characteristic Properties.
1	Liquid Vegetable Oils.	Olive,	0.915 to 0.917	Solidification, Elaidin melts at 32°	35°	94°	500 to 544	80 to 84	4.7	+ 1 to 4°	27°	23°	17.86	43	0.6 Sacchar.	1. *Action of Nitrous Vapors.*—Operate by Cailletet's process, pouring on twenty grams oil six grams H_2SO_4 and nine grams HNO_3. The characteristic colorations are first, with H_2SO_4 green, second, with H_2SO_4 + HNO_3 gray, green; third, after boiling straw-yellow, H after cooling a hard mass color of white butter
2		Peanut,	Unshelled, 917.5; Shelled, 921	Liquid Mass.	46°	127°	530	97	3.5	— 1°	31°	28°	17.82	66	Variable.	2. Arachidic acid, $C_{20}H_{40}O_2$ (fusing point 75°), is characteristic and allows the detection of peanut oil in all oils containing it.
3		Sesame,	923	"	54°	150°	695	104	3.4	— 5°	26°	22°	17.70	41	"	3. *Mailliau's Process.*—The red color obtained by treating the rectified fatty acid of the oil with hydrochloric acid, and sugar is characteristic. The fatty acid is first collected and melted in an oven.
4		Cotton-seed (edible),	922	"	52°	144°	645	108	15.3	— 12°	36° to 37°.5	35°	18.17	62	"	4. *Mailliau's Process.*—The black color obtained by the reduction of $AgNO_3$ in the presence of the saponified products of the rectified oil is characteristic.
5		Poppy (drying),	925	"	80°	222°	835	133	13.1	— 18°	20°.5	16°	18.13	45	— 0.7°	5. Poppy oil when used as an adulterant of olive oil, prevents the solidification of the mass by the action of nitrous vapors.
6		Colza,	914.5	"	48°	133°	640	99	6.3	— 6°.5	17°	16°	16.49	20	Variable.	6. A solution of potassium hydroxid heated with saponified colza oil blackens with lead acetate, and reddens with potassium nitroferrocyanid.
7		Rape seed,	915	"	56°	155°	632	103	5.9	— 4°	15°.5	15°	16.68	15	+ 10°	7. Density and fusing points of the fatty acids
8		Linseed,	932.5	"	121°	336°	1,000	156	8.7	— 27°.5	23°	21°	17.98	70	Inactive.	8. Density, freezing point, sulfuric saponification and iodin index
9		Walnut,	926	"	99°	275°	737	144	7.3	— 30°	Fluid.	Fluid.	18.26	44	"	9. Sulfuric saponification, iodin index, freezing points and fluidity of the fatty acid.
10		Cameline,	926	"	51°	141°	817	132	7.5	— 18°	"	"	17.90	78	— 3	10. Iodin index, freezing point and fluidity of the fatty acid.
11		Beechnut,	921	"	59°	163°	652	106	6.1	— 18°	24°	17°	18.18	45	Almost Inactive.	11. *Brullé's Reagent.*—Two cubic centimeters nitric acid, one gram dried albumen, ten cubic centimeters oil; when agitated the mixture takes a characteristic vermilion tint
12		Mustard seed,	918	"	39°	108°	763	96	6.9	— 5° to 0°	16°	15°	17.97	28	+ 3	12. Sulfuric saponification and iodin index.
13		Sweet almond,	918.5	Soft Consistence.	47°	130°	644	98	5.7	— 10°	14°	5°	18.22	39	Almost Inactive.	13. Nitrous vapors and solidification of fatty acid.
14		Hazelnut,	917	Rather Firm.	31°	86°	561	87.5	4.9	— 21°	25°	23°	17.63	33	"	14. Sulfuric saponification and freezing points.
15		Castor,	965	Formation of Ricin-Elaidin.	40°	111°	559	84	15.3	— 16°	14°	4°	16.77	Soluble.	Mean = 43	15. Density, solubility in alcohol and crystallizable acetic acid, insolubility in petroleum ether, deviation of the plane of polarization.
16	Solid Vegetable Fats.	Coprah,	924.5	Solidification.	17°.5	48°.5	74	12	—	Solid 22°.5; Fusion 26°	26°.5	22°.7	24.1	Soluble at 31° C. in 2 vol. alcohol.	Undetermined.	16. *Mailliau's Process.*—The neutralized oil is soluble at 31° in twice its volume of absolute alcohol, and becomes insoluble on the addition of seed oils. Saturation, iodin index.
17		Cabbage palm,	922	"	19°	52°.7	99	16	—	23°.5 26°.5	27°	24	22.5	Soluble at 31° C. in 4 vol. alcohol.		17. *Mailliau's Process.*—Like the preceding, but requires four volumes of absolute alcohol.
18		Palm,	915	"	17°	47°	315	51	—	25° to 35° 33° to 39°	46° to 47°	42° to 46°	18.5	400		18. Density, sulfuric saponification, partial solubility in absolute alcohol.
19		Mowrah,	915	"	26°	71°	404	65.3	—	23° 27°	46°	42°.5	15.5	160		19. Density, saturation, when shaken with alcohol gives a characteristic milky tint.
20		Margarin from cotton-seed oil,	920	Soft Consistence.	47°.5	136°	588	84	—	14° 28°.3	46°	42°.5	18.2	61		20. Iodin index, solidification of the oil; Mailliau's Process 4.
21		Illipé,	917.5	Solidification.	13°.5	37°	152	24.7	—	26° 39°	56°	52°.5	17.7	260		21. Sulfuric saponification, iodin index, fusing point of the fatty acids.
22		Karité,	917.7	"	28°.5	79°	416	67.2	—	23° 25°.5	56°.5	52°.5	14.9	80		22. Fusing point of the fatty acids, saturation, when agitated with alcohol gives a characteristic milky tint.
23	Solid Animal Fats.	Butter,	920 to 936	Solidification.	Mean, 23°	Mean, 63°	160 to 216	26 to 35	—	19° to 31° 21° to 32°	37° to 39°	35° to 37°	21.15	65.4		23. Volatile fatty acids, iodin index, solidification of the neutral matter saturation, microscopic examination.
24		Suet,	Mutton, 917; Beef, 915	"	16°	44°	247	40	—	33° to 36° 42° to 46°; 33° to 35° 38° to 43°	40° to 50°; 40° to 48°	45° to 47°; 43° to 45°	18.5; 18.25	3.18		24. Sulfuric saponification, solidification of the fatty acids, insolubility in absolute alcohol.
25		Lard,	920	"	33°	91°	365	59	—	32° 34°	35°	34°	18.12	43		25. Sulfuric saponification, iodin index.
26	Miscellaneous.	Fish oil,	923 to 930	Liquid Mass.	50° to 100°	136° to 277°	761 to 872	123 to 141	—	Congeals at 0°	—	—	17.71	Cod Liver, 240		26. Iodin index, solubility in alcohol (milky emulsion), fusion point of cholesterin.
27		Rosin,	1.08	—	—	—	718	116	—	—	—	—	15.13	Soluble.	Mean = — 15°	27. Density, saturation, solubility in alcohol, deviation of the plane of polarization
28		Rosin oil,	960 to 990	Fluid Mass.	—	—	297	48	—	—	—	—	—	Almost Insoluble Cold.	+ 30°	28. Density, deviation of the plane of polarization, insolubility in crystallizable acetic acid.
29		Commercial olein (oleic acid),	900	Solidification. Elaidic Acid.	24°	—	443 to 518	68.5 to 83.5	41 to 63	—	+ 4° to + 12°	0° to + 8°	17.7	Soluble.	—	29. Density, nitrous vapors, solubility in alcohol.
30		Mineral oils,	850 to 930	Liquid.	Petrol., 3°; Schist, 22°	8°; 61°	80; 130	13; 21	—	—	—	—	—	Insoluble Cold.	—	30. Density, iodin index, insolubility in alcohol.

Tallow is detected by observing, under the microscope, the crystallization of the fat from ethereal solution.

VARIOUS OILS.

The following oils, which frequently are used for the adulteration of agricultural fatty materials, are easily detected:

Fish Oil:—by its iodin number, its solubility in absolute alcohol, the presence of cholesterin, and finally the brown coloration by chlorin, and red by caustic soda and phosphoric acid.

Resins:—by their density, their saturation, their solubility in absolute alcohol, and the deviation of the plane of polarization. Besides, it is easy to isolate them because the majority of compounds which they form with metallic salts are soluble in ether while those of the fatty acids are insoluble.

Resin Oils:—by their property of not saponifying with caustic soda, by their insolubility in glacial acetic acid, and by the characteristic purple coloration which they give with fuming stannic chloride.

Olein Oil of Commerce:—by its solubility in alcohol and by its specific gravity.

Finally, the mineral oils:—by their iodin numbers, their indifference to the action of caustic soda, and their insolubility in absolute alcohol at 15° C.

Gentlemen, we have nearly finished all we have to say in our lecture. The processes which we have just enumerated are applicable indiscriminately to fatty matters, both edible and industrial, for the determination of their purity, with an approximation sufficient for the majority of cases. The results obtained will be more conclusive if they are compared with those from products of the same origin and known purity. Banish the thought that in this short discourse we have wished to indicate in an absolute manner those processes which must be used and those which should be rejected. We have desired only to explain the methods which have given us the best results in the thousands of analyses which we have had occasion to make on fatty materials, including 50,000 for olive oil alone.

Although most of the processes which I have just indicated were devised and perfected in our laboratory, and have been adopted by several governments, I have not, however, the presumption to feel that we have definitely finished this question. I consider, on the contrary, that in the vast unexplored region of the fatty series, we have only taken a few steps; but I feel at the same time that we are now in the possession of sensitive and scientific methods which permit us to detect mixtures, the determination of which has appeared impossible up to the last few years.

The mission with which I have been charged by the French and Tunisian Governments in the interests of commerce and industry, shows you to what extent these countries are desirous of facilitating the exportation of pure and satisfactory products. France furnishes the best growth of virgin olive oil, from Aix en Provence and Nice. Tunis, also, furnishes, but at a less price, olive oils of excellent quality, which we can certify without analysis, because the Government imposes such heavy export and import duties upon seed and seed oils that it would be impossible to practise the smallest amount of sophistication.

Those who deal in olive oils often make the remark that pure oil is too strong and that it is improved in flavor by a mixture with seed oil. Without discussing this inexact statement, I believe that it would be preferable in every instance for the dealer to buy pure olive oil and to make his own mixtures. He would thus profit by the difference in price, which averages about sixty francs per 100 kilograms.

I hope you will pardon the dryness of the subject which we have just discussed, in considering how important it is for our two countries to have the same means of making analyses of American and French products. When we arrive at a complete understanding, discussions and reclamations will become impossible, and I cannot better conclude than by expressing the sincere wish that its realization will permit the two republics to bind more closely together their commercial relations.

Thanks, gentlemen, for your kind attention.

THE ATOMIC WEIGHT OF MOLYBDENUM.

BY EDGAR F. SMITH AND PHILIP MAAS.

[*Read before the Chemical Section of the Franklin Institute, September 19, 1893.*]

The present atomic value assigned this element is based upon the results obtained by Dumas (*Ann. Chem. Pharm.*, **105**, 84, and **113**, 23), Debray (*Compt. rend.*, **66**, 734) and Lothar Meyer (*Ann. Chem. Pharm.*, **169**, 365). The method pursued by Dumas consisted in the reduction of molybdenum trioxide. Debray also adopted this procedure, but in addition made several experiments upon the precipitation of the trioxide in an ammoniacal solution by silver nitrate. Lothar Meyer's value (95·9) is deduced from results obtained by Liechti and Kemp (*Annalen*, **169**, 344) in their analyses of the chlorides, $MoCl_2$, $MoCl_3$, $MoCl_4$ and $MoCl_5$. The chlorine in each was determined as silver chloride and the molybdenum as disulphide. Clarke (*A Recalculation of the Atomic Weights*, Washington, 1882) expresses the opinion that the most reliable results are those that have been obtained by the reduction of the trioxide. Of the work of Liechti and Kemp, he remarks: "Traces of oxychlorides may possibly have contaminated the chlorides and augmented their atomic weight." Rammelsberg (*Berichte d. d. Chem., Gesellschaft*, **10**, 1776) made one experiment in the reduction of the trioxide, from which he calculated the atomic weight of molybdenum to be *96·18*.

Thinking that additional light could be thrown upon the magnitude of this constant by proceeding in a different direction, we utilized a reaction first observed by Debray (*Compt. rendus*, **46**, 1098; *Ann. Chem. Pharm.*, **108**, 250), which, in the hands of others (Péchard, *Compt. rend.*, **114**, 173; *Zeit. f. anorg. Chem.*, **1**, 262; Smith and Oberholtzer, *Journ. Am. Chem. Soc.*, **15**, 18, and *Zeit. f. anorg. Chem.*, **4**, 237) has proved to be a most excellent means of determining molybdenum and separating it from its intimate associate—tungsten. We refer to the action of hydrochloric acid gas upon molybdic

acid and molybdates, whereby the molybdic acid is volatilized with ease in the form of an hydroxychloride—$MoO_3.2HCl$. Numerous trials have demonstrated that the reaction expressed by the equation—

$$Na_2MoO_4 + 4HCl = 2NaCl + MoO_3.2HCl + H_2O$$

is quantitative. We exposed pure anhydrous sodium molybdate (at 150–200°) to the action of hydrochloric acid gas, volatilized the molybdenum, trioxide and from the weight of the residual sodium chloride calculated the atomic weight of molybdenum.

The sodium molybdate employed by us was Merck's purest preparation. We recrystallized it many times and then by a careful examination satisfied ourselves that it did not contain silica, sulphates, tungstates or alkaline carbonates—substances that might have been present. The purified salt was dried with extreme care until no further loss in weight was observed. In this anhydrous condition it was preserved in clean weighing bottles, which were kept in desiccators to exclude dust and moisture. The specific gravity of the anhydrous salt was determined, alcohol being used for the purpose. The value found was 6·9780. The balance employed by us was of the Sartorius design.*

The weights of brass and platinum were of Westphal make and had previously been carefully adjusted for this purpose.

Tared porcelain boats were used to carry the anhydrous sodium molybdate, which was exposed in hard glass tubes to the action of pure and dry hydrochloric acid gas. This was prepared from salt and pure sulphuric acid. The gas as it was evolved was first conducted through a U-tube half-filled with damp silver chloride; it next passed through two flasks containing sulphuric acid, then through a tower of dry calcium chloride and finally through clean cotton, after which it was admitted to the combustion tube where it came in contact with the sodium molybdate. A very gentle heat was applied to the latter and gradually

* We would here acknowledge our indebtedness to Dr. John Marshall, of the Medical Department, for the privilege of using this excellent instrument.

increased to from 150–200° C., beyond which the temperature was not permitted to rise. Moisture was excluded as much as possible. The volatilized $MoO_3.2HCl$ was collected in water. The boats containing the residual sodium chloride were allowed to cool in a slow current of hydrochloric acid gas, then transferred to vacuum desiccators, and the vapor repeatedly exhausted. The weights were taken after the boats had stood one hour. Second weighings were made after the boats had remained overnight in the dry desiccators and showed no appreciable alteration. Barometric pressure and temperature were carefully observed and all weighings reduced to the vacuum standard. Our results are as follows:

Na_2MoO_4 in Grams.	*NaCl in Grams.*	*Atomic Weight of Mo.*
1·14726	0·65087	96·130
0·89920	0·51023	96·094
0·70534	0·40020	96·108
0·70793	0·40182	96·031
1·26347	0·71695	96·087
1·15217	0.65367	96·126
0·90199	0·51188	96·067
0·81692	0·46358	96·077
0·65098	0·36942	96·073
0·80563	0·45717	96·078
Mean, ... =		96·087
Maximum, ... =		96·130
Minimum, ... =		96·031
Difference, ... =		·099

In our calculations we used the following values: Na = 23·05, Cl = 35·45 and O = 16. These have been taken from a revised table of atomic weights, published by Clarke, October, 1891.

The sodium chloride in five of the determinations just given was converted into silver chloride. From the calculated silver contained in the chloride we deduced the atomic value of molybdenum to be 96·10—the mean of five determinations. This figure we regard as confirmatory of the rest of our work.

The sodium chloride which we obtained dissolved readily

and to a clear solution in water. Molybdic acid was not found present in it. This was one of the points that we watched very closely, although its presence would have tended to diminish rather than to augment the atomic value found. Another cause of a like result would have been moisture absorbed by the sodium chloride. Against this source of error we likewise took every precaution, and consequently feel that the result *96·08* obtained by us approaches very closely to the true atomic magnitude of molybdenum.

UNIVERSITY OF PENNSYLVANIA, September 16, 1893.

THE ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, September 27, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 27, 1893.

ELMER G. WILLYOUNG, President, in the chair.

The stated meeting of the Electrical Section was called to order at 8·10 P. M., by President Willyoung, with twenty-one members and visitors present.

The minutes of the meeting of June 27th were read and approved.

The Treasurer reported a balance of $35.89 on hand, and presented bills for printing, $3, and postage and mailing of notices, $8.75, which were ordered paid.

A paper on "The Chloride Electrical Storage Battery," by Mr. Herbert Lloyd, was read by the author and discussed by Messrs. Hering, Spencer and Willyoung.

The meeting then adjourned. R. H. LAIRD, *Secretary.*

[*Proceedings of the stated meeting, held Tuesday, October 24, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 24, 1893.

ELMER G. WILLYOUNG, President, in the chair.

The stated meeting of the Section was called to order at 8 P. M., by President Willyoung, twenty-three members present.

In the absence of the Secretary, on motion, Mr. D. A. Partridge was appointed Secretary *pro tem.*

The reading of the minutes of the previous meeting was dispensed with.

The names of Mr. Bacon, E. R. Keller and G. C. Common having been proposed for membership, they were duly referred to the Committee on Admissions.

The Chair announced that a series of lectures, to alternate with the business meetings of the Section, had been arranged for, and that Dr. Henry Morton, Mr. J. J. Carty, Prof. Elihu Thompson and one or two others had expressed their willingness to address the Section.

Mr. Carl Hering read a most interesting collection of notes on "Recent Progress in Electricity Abroad," taken mostly from European journals.

Some interesting discussion was elicited upon many of the points touched upon in Mr. Hering's paper.

Mr. L. F. Rondinella exhibited a collection of lantern slides of subjects from the Columbian Exposition, and gave a short talk descriptive of the views.

On motion, adjourned. D. ANSON PARTRIDGE, *Secretary pro tem.*

NOTES ON RECENT DEVELOPMENTS IN ELECTRICITY ABROAD.—PART I.

BY CARL HERING.

[*A paper read at the stated meeting of the Electrical Section of the Franklin Institute, October 24, 1893.*]

Busy men, as most conscientious electricians are, generally have little time to study the vast amount of periodical literature published weekly, even if the journals were all accessible to them, and if the foreign languages in some of them were no hindrance. For the benefit of such busy men the following notes were compiled from articles in the principal foreign electrical journals for the present year; as they are all taken from periodicals, they necessarily contain nothing which has not already been published, and they are therefore intended to form a mere *résumé* or index to call attention to what has been done, leaving those who are interested in any of the subjects to look up further details for themselves.*

Electro-physics.—Taking up first the subject of electro-

---

* More complete abstracts of all the articles referred to will be found in the "Digest" of the *Electrical World*, from February 4, 1893, to date.

physics, I will limit myself to only a few of the more interesting papers, as most of that which has been published in this branch belongs to the subject of physics rather than to electrical engineering.

Mr. Arno has shown that a rotating electric field, quite similar to the well-known rotating magnetic field, can be produced, and that this can be applied to the construction of an electrostatic rotary field motor; it is only of theoretical interest, as the power developed is necessarily exceedingly small. There has been some discussion as to whether there is such a thing as electrostatic hysteresis, on which this phenomenon is supposed to be based, but authorities still differ.

Prof. Elihu Thomson states that he has succeeded in making a transformer in which a continuous current is made to give alternating currents of any desired frequency, and which contains no moving parts. Several other writers have shown how the frequency of an alternating current may be tripled and doubled quite readily in an alternator without increasing the speed. Dr. Sahulka has shown that a condenser may act as a transformer of current into phase, so to speak, that is, that a condenser in parallel converts a weak current of small phase difference into a strong current of large phase difference, and *vice versa*.

Several instruments have been described by means of which the curve of an alternating current can be resolved into its component sine curves.

Dr. Heydweiller has made a long series of tests with striking distances, giving quite a complete table of the results, which might be used to advantage in place of the very old table of De La Rive, which has been the standard of reference for so many years. The much-vexed question of the sparking distances has also been discussed by Mr. Peace, in a Royal Society paper, in which he gives what constitutes, probably, one of the most complete and reliable tests made for certain ranges. Mr. Precht has shown that lightning-rod points begin to discharge only when the potential has reached as high as 15,000 volts, and even extremely fine points can be charged to 2,500 volts before they will

discharge continuously; also that a bunch of points must be charged to a higher potential than a single point in order to discharge; he believes that in many cases the points of lightning rods are inactive. The difference of potential of the air at the top and at the bottom of the Eiffel Tower was found to vary from 3,000 to 7,000 volts, increasing sometimes to 10,000.

Mr. Arons described an arc lamp in which the arc is produced in vacuum between electrodes of mercury, showing some interesting results; the voltage and the current are quite low, but unfortunately the amount of light generated is not given.

In an interesting experiment made by Dr. Gore, he has shown that mechanical pressure may be converted into an electric current; the pressure is applied to an electrolyte, which then generates a current at the expense of nothing but the pressure.

A number of improvements have been described by Wimshurst and others in so-called electrostatic machines.

Numerous experiments have been described with stretched wires through which a current is passed; under certain conditions the wire will vibrate, some parts becoming luminous, while others remain cold; in another case the wire itself became deformed as if it had been placed between two files.

A number of articles have been published on the electrical transmission of sight, but although interesting, they appear to contain nothing new or of any great importance, and the matter may still be considered as an unsolved problem.

Much has been done in the line of the researches started by Hertz, but this is beyond the province of the present paper.

Professor Dewar has made some very interesting experiments with liquid oxygen, which he now makes in large quantities. Liquid oxygen is magnetic, and he has shown that in liquefied air the magnet will not suck out the oxygen, even though the nitrogen is not magnetic. But the most interesting parts of his researches, for electricians, are those which show that the resistance of all pure metals is probably zero

at the absolute zero of temperature; or, in other words, at that temperature electricity will pass through pure metals without any C^2R loss; alloys, however, do not follow this rule. Professor Dewar has also succeeded in converting air into a solid. It has been stated that the magnetic moment of oxygen is about one-thousandth that of iron, and that liquid oxygen is an excellent insulator.

Much has been written on the electro-magnetic theory of light, but it is beyond the province of this *résumé*. An English scientist stated that electro-magnetic waves are strictly similar in their nature to light waves, differing only in the wave length. The light waves are about one-fifty-thousandth of an inch long, while the electro-magnetic waves that have been investigated are from a few inches to many yards in length.

Messrs. Lagrange and Hoho gave what appears to be the first published description of the phenomenon, now so well known, of heating a metal by its contact resistance with water. The heat produced is exceedingly intense, and is generated very rapidly—two qualities which may make the process one of considerable commercial value.

It is claimed by Mr. Sanford that Ohm's law should be qualified, as he believes that he has found that the nature of the medium surrounding a wire has an appreciable effect on the resistance of the wire; his conclusions, however, do not appear to be generally accepted, and it will be fortunate if it turns out that he is not correct.

Mr. Packey claims to have found by photography that there is what he calls an electrical spectrum different from the remaining part of the spectrum, and that it contained only the "electric rays" of the spectrum.

Several papers have been written, showing how the amount of light can be measured by absolute instead of comparative methods, but none of these appear to have as yet been put into the form of a practical photometer.

A number of interesting phenomena have been described with high tension and high frequency currents, which, however, time does not admit of mentioning here. Much has been written lately endeavoring to explain the phenomenon

that an incandescent lamp may be brought to great brilliancy by high tension, high frequency currents of exceedingly small ampèrage; most of the writers claim that it is due to skin-deep conduction, but this has been seriously questioned by several equally high authorities, and it can therefore still be considered as a phenomenon which cannot be explained. Dr. Leduc has shown that high tension alternating currents produced by electrostatic machines have properties which are analogous, but not identical with, those which Tesla uses. Mr. Rimington has shown that many of the phenomena with vacuum tubes can also be produced with such tubes when they contain no electrodes, and when they are placed in electrostatic fields. Lord Armstrong showed an interesting experiment, in which a cotton thread was carried bodily from one glass of water into another by a current from an influence machine.

A new and important re-determination of the mechanical equivalent of heat has been made by Messrs. Griffiths and Clark; they found it to be 778·99 foot-pounds.

Among the interesting articles of a speculative nature is one in which a French writer endeavors to show that the absolute temperature has the same dimensions as electrical potential.

Magnetism.—Mr. Meylan has shown that the great care taken by some makers to have perfect joints in dynamos is not justifiable, as the additional excitation required to overcome the effects of joints in a magnetic circuit is only about one to two per cent.; in transformers, however, the question is quite different, for if joints could be avoided, there would be a gain of ten to fifteen per cent. in the magnetizing current; he believes furthermore that the pre-determination of the characteristics of transformers having a closed magnetic circuit is very uncertain, and probably of little practical value.

Mr. Abdank Abakanowicz has described an interesting arrangement by means of which the effects of hysteresis may be compensated in measuring instruments by the simple addition of a second electro-magnet, properly designed and proportioned.

In Russia, a local north pole of the earth's magnetism has recently been found, thus showing that there are at least two north poles of the earth.

Units, Measurements and Instruments.—Many new instruments and new methods for making various measurements were described, but they are too numerous to mention here. Those interested in the measurement of self-induction will find several articles on the subject in recent numbers of *La Lumière Électrique.* Professor Fleming, in his recent Cantor lectures, has given a very good summary of the subject of the practical measurement of alternating currents.

The very extended researches which have recently been made with the Clark standard cell seem to show that it may now be considered as a very reliable and accurate standard, provided it is properly made. On the other hand, it appears that the Daniell standard has been abandoned, at least when accuracy and reliability are of great importance. It appears that the Clark cell may now be relied upon within one part in 10,000; that is, within one-hundredth of one per cent.

A number of tests have been made of the Elihu Thomson wattmeter, all of those published giving very favorable results; this, coming from abroad, is significant. Professor Fleming has called attention to the fact that meters placed in cellars are often subjected to great changes of temperature, producing an error of from ten to fifteen per cent. in the readings, a subject which he thinks ought to be considered more than it is in designing meters. Several forms of ohmmeters have been described, chiefly for use in measuring high resistance and insulation. The literature on the copper voltameter has received an important addition by the paper of Dr. Ottel; he shows, among other things, that the addition of alcohol makes the actual deposit more nearly equal to that required by theory; also, that an acid solution is better than a neutral one.

Much has been written about locating faults in underground mains, but most of the methods are either impracticable or rather cumbersome, requiring the patience of a German to apply them. Apparently successful high resistances have been made, consisting of rods of a mixture of

plumbago and clay. An interesting and simple method for measuring the magnetic qualities of iron was described by Dr. Behn-Eschenburg, in which the underlying principle is that the magnetic circuit is suddenly broken, which enables both the permeability and the residual magnetism to be readily determined with very simple apparatus.

Much has been written, especially by the French and Germans, regarding the behavior and the calculation of condensers for commercial use in alternating current circuits; although interesting, the results will be of little use until condensers become cheap enough to be used in practice. A feature of interest, if true, for all condensers, was reported in an English paper; it was shown that a condenser which was excellent at normal temperatures, possessed very bad insulation when the temperature approached the freezing point of water.

Recent experiments with the arc have apparently shown that its temperature is constant, being about 3,500° C., and that the amount of light emitted per unit area of crater surface is also constant, for which reason some have urged its adoption as the unit of light; the amount of light given off per square millimetre of crater surface is given as about seventy candles. A French scientist suggests a photometric standard made of phosphorescent zinc sulphide, which, in common language, might be called luminous paint. If exposed to the light it will afterward emit light, the intensity of which seems to be independent of the original source of illumination, of its duration, and of the thickness of the layer. Among the different forms of photometers the Lummer-Brodhun type seems to be meeting with increasing favor. Several curious forms of photometers have been described, in one of which light is absorbed and measured by a semi-translucent screen of increasing thickness, and, in another, letters printed on successive sheets, each one with a darker background than the preceding, are used, but both are, of course, only very crude instruments.

For measuring extremely high temperatures, as in furnaces, and also for extremely low temperatures approaching the absolute zero, physicists seem to have found electrical

methods the most reliable. For high temperature thermometers, Dr. Barus concludes from a long series of experiments that a couple made of platinum with an alloy of platinum and iridium or rhodium gives the best results.

Mr. Lagarde has made a re-determination of the specific resistance of pure copper, and finds it to be 19·58 ohms, presumably legal ohms, at 0° C. for a wire 1,000 metres long and one millimetre in diameter. He also found that the temperature coëfficient ·00445 is fairly constant between 0° and 40° C., and that it is directly proportional to the conductivity of the copper.

A writer in a German paper calls attention to the fact that the shape of the waves of an alternating current will have quite a perceptible effect in the reading of a voltameter and in the working of an alternate current arc light, and he concludes therefrom that both should be adjusted with currents from the same generator with which they are to be used.

A French writer has devised an analytical method for determining the shape of the curves of alternating currents, consisting of an experimental determination of the successive terms in the Fourier series, from which the curve can then be deduced. The measurements are made with auxiliary apparatus used in connection with the alternator.

There was much discussion in foreign journals regarding the work to be done by the Chicago Congress, but as all this was entirely ignored by the delegates to that Congress it may be passed over here. Although it has been of little use, it was none the less interesting and instructive.

CHARLES A. COULOMB.

By Prof. Edwin J. Houston.

[*Read before the Electrical Section of the Franklin Institute at its stated meeting, March 28, 1893.*]

The eminent services of Charles A. Coulomb to physical science generally, and to the field of electricity and magnetism in particular, have long been recognized by the scientific world. When the custom arose of naming the practical electric units after distinguished electricians or physicists who had passed from their labors, Coulomb was remembered and the practical unit of electric quantity was named after him.

Portraits of all the scientists after whom the units of electricity are named, have been published, with, I think, the exception of Coulomb.

One of my former students, a grandson of Coulomb, has loaned me a eulogy on his grandfather by Delambre. This eulogy gives an excellent account of the civil and scientific services rendered by Coulomb to the world, and I have thought that a translation of the same, together with a photograph, taken from an oil painting now in the possession of the Coulomb family, might be of interest to the electric public.

I have, therefore, made a free translation of the article. The manuscript is in that illegible handwriting so often characteristic of genius. Indeed, this is true in the present case to such an extent that in all probability I may have erred in some respects in my translation. I believe, however, that this will be true to but a limited extent, especially as Prof. Bernard Maurice, Professor of French in the Central High School of Philadelphia, has kindly given my translation the benefit of his criticisms.

Although the translation can best speak for itself, yet a brief summary of the more important of M. Coulomb's contributions to physical science may be of interest.

The field which M. Coulomb occupied in science was a

varied one. His earlier work comprised the construction of submarine works with means for laying foundations without previous drainage.

He also early in life conducted a series of investigations as to the efficiency of man as a prime mover, and made various calculations as to the amount of work that a man can do when obliged to spend his power for the driving of machinery. Later on in life he was awarded by the French Academy a prize for a theory of simple machines, and conducted an extensive series of experiments concerning the strength of materials and the friction of one body over another, either when in motion or when started from a state of more or less prolonged rest.

In connection with M. Swinden he was awarded the prize by the French Academy for the best construction of compasses.

The contribution to physical science, on which it may be said that M. Coulomb's reputation mainly rests, was the invention of the torsion balance, by means of which he conducted that extensive series of experiments in electrostatic and magnetic attractions and repulsions, which won for him a lasting reputation as an experimental philosopher of the highest type.

In the construction of the torsion balance, he established the law that the force producing the torsion of a wire is directly proportional to the angle of torsion.

It was by means of this balance that Coulomb established definitely the law that magnetic and electric attractions and repulsions between two bodies are inversely proportional to the square of the distance.

It may be of interest to the Section to note that Coulomb proposed a theory of magnetism which bears a remarkable resemblance to some of the theories of magnetism propounded during later days.

Coulomb imagined that the molecules of a magnetized bar consist of numerous separately magnetized particles, with their opposite poles in contact, and showed how the opposing actions of such poles, would, for the greater part, neutralize each other, leaving the two extreme poles alone

to act freely as centres of action at the ends of the bar. By a series of extended investigations he showed that the property of magnetism was by no means confined to iron, obtaining unequivocal signs of attraction in all of the many substances that he subjected to experiment. Nor did he ascribe this property of magnetizability to the presence of iron in the different bodies, which he found were susceptible to the magnetizing force; for, as he himself pointed out, in order to permit this supposition to be true, it would be necessary to assume so considerable a quantity of iron distributed throughout the substance, that it could not have failed to manifest itself to even ordinary chemical analysis.

Coulomb made a study of the distribution of magnetism in a magnetic needle, showing that the magnetic force is very feeble throughout nearly the entire length of the needle, but is concentrated at two points near the ends, *i. e.*, at its free poles.

It was in connection with the above studies concerning the distribution of magnetism in a needle, that Coulomb sought for an analogous distribution in an electric charge, and showed by means of his investigations that an electric charge, which is so powerful at the surface of bodies, penetrates the interior but slightly, and, at the same time, ascertained the law according to which an electric charge distributes itself over conductors of different dimensions.

His investigations also extended to the action of points on the discharge of electrified bodies.

In the domain of magnetism Coulomb constructed an improved inclination compass and proposed methods for the production of artificial magnets. He also investigated the effects which temperature produces on magnetism, calculating the temperature to which it would be necessary to heat a magnetized needle in order to deprive it entirely of its magnetism.

The brief review which I have made concerning the extended discoveries of Coulomb, when taken in connection with the translation, will, I think, show the importance of his scientific work.

THE INSTITUTE OF FRANCE.

ACADEMY OF SCIENCES.

The Perpetual Secretary of the Academy certifies that the following is an extract from the memoir of the Class of Mathematical and Physical Sciences of the National Institute of France, vol. 7, Second Semestre, p. 206:

HISTORICAL EULOGY OF CHARLES H. COULOMB.

By M. DELAMBRE.

[*Read at the Public Séance of the 5th of January, 1807.*]

Charles Augustus Coulomb, Lieutenant Colonel in the Engineer Corps, Chevalier of St. Louis, Member of the Academy of Sciences, and afterwards of the Institute and of the Legion of Honor, one of the Inspector Generals of Education, was born on the fourteenth day of June, 1736, at Angoulême, of a family which was distinguished in the magistracy of Montpellier.

Coming at an early age to Paris, he manifested so decided a taste for the mathematical sciences that he determined to devote himself entirely to them: but, finding some obstacles to the execution of this project, he entered the Military Engineer Corps, where he at least hoped to use for his advancement that knowledge the pursuit of which was his sole passion, and, in order to achieve more promptly the end of his ambition, he determined to go to America, where he was employed by the Government in the construction of public works of the greatest importance. Here some work undertaken during hot weather seriously affected his health. The cruel malady by which he was attacked, and which had been fatal to all his co-workers, made him desirous of returning to France. His superior officer, however, kept him in the service by the higher rank to which he raised him and by inspiring hopes which were unfortunately never realized. He finally returned to France after nine years' absence. Up to this time he had given himself unsparingly to his profession. He brought to this work, as means for carrying

out with greater economy and solidity the various constructions which he directed, that spirit of experimental research and calculation which so eminently distinguished him. The observations and theories which had guided him in such work furnished materials for a memoir which he read before the Academy of Sciences, and which secured for him the title of Corresponding Member.

About the same time he designed methods for carrying on submarine works without previous drainage, and invented a species of wheel which appeared to him similar in its operation to a windmill, and tested its efficiency by comparing the useful effect with the effect lost by blows and by friction.

We would refer to this epoch a memoir, which, however, he did not publish until twenty-five years afterwards, but which he read before the Academy in 1775. In this memoir he estimated the quantity of work which men can furnish in their daily labor, according to the manner in which they employ their strength. The aim of these researches, undertaken at different epochs of his life, was to diminish the fatigue of man when obliged to act as a simple machine.

In 1779 he shared with M. Swinden the prize offered by the Academy for the best construction of compasses. Two years afterwards he carried off the prize offered by the same society for a theory of simple machines.

Amontons had published some experiments on the same subject, but these experiments, being conducted on a small scale, in the physical laboratory, were insufficient to correctly estimate the friction of machines designed to carry great loads. The first thing to do then was to design an apparatus that could be loaded with enormous weights, which would permit of variations in the trials, of the calculation of the effects, and of the observation of the friction of different bodies, either dry or covered with unguents, sliding over one another in different directions, both while in motion, or when started from a more or less prolonged state of rest. M. Coulomb who then lived at Rochefort, found in the Marine Arsenal, by the kindness of the Commandant M. Touche Treville, everything which could facilitate this

new and important research. The Academy, in crowning this work, testified their satisfaction both as to his theory and as to his experiments.

These two researches possessed that characteristic which M. Coulomb had impressed on all his works. In the one, as in the other, we observe his close attention to the interrogation of nature and his ability to seize and verify everything of importance, to search in rational mechanics for the formulæ best suited to connect the isolated facts, and to try new experiments, and, by varying them in a suitable manner, to endeavor to determine the kind of formulæ and the quantities which could be varied according to the nature of the substances submitted to experimentation.

It has already been said of those who have distinguished themselves by the advancement of new views, that the germs of their discoveries were contained in their first work; that their later productions have been but enriched and matured developments of their earlier ideas.

We have a new proof of this saying in the labors of M. Coulomb, which are to be ranked among the most advanced in physics.

In the competition for a prize on the compass, one of his competitors indicated a means for avoiding the effects of torsion; that is to say, the resistance which the suspended wire offers by its rigidity to the force of magnetism, tending to deflect the needle in a constant direction. M. Coulomb endeavored to familiarize himself with these effects of torsion, and even described at that time an apparatus for measuring with accuracy the forces of torsion, but he could not find a mechanic capable of constructing the apparatus he had designed, and this, his first conception, announced while undeveloped, no doubt contributed in some degree to the success he afterwards achieved.

There is no little difficulty in appreciating all that is contained in these first suggestions, all that was born in this early conception.

In 1781, M. Coulomb continued his labors in Paris. The Academy was eager to admit him to membership. All his thoughts were now turned toward those researches on mag-

netism and electricity which formed both his chief glory and the richest collection of the Academy. Here he completed his successive labors and discoveries.

In order justly to appreciate the services which M. Coulomb has rendered to physics, and to understand the advantages of his methods, let us take a brief glance at the state of physical science at different epochs.

The ancients were acquainted with physics in name only. To be convinced of this fact, it will suffice for one to read, if able to do so, the numerous treatises of Aristotle, not so much on the general subject of physics, as on the heavens, generation, corruption and meteors.

We will remark that in all of these are contained numerous dissertations on space, time and the principles of the elements. What advantages can one draw from this obscure mass of unintelligible metaphysics? What can we understand in the very brief treatises in which Plutarch has rendered but poor service to the Grecian philosophers, by condensing their opinions in an exceedingly brief space as if he wished by the collection the better to turn them to ridicule?

What do we see in these treatises, unless it is that, satisfied with an insufficient examination into some phenomena of nature, the authors had been afforded an opportunity of exercising their imagination on such phenomena, without being able to invent any of those ingenious machines which aid in the investigation of nature; so that with the single exception of some of the striking truths found in the writings of Archimedes concerning his inventions, together with some other of the geometricians and mechanicians of Alexandria, amongst which we find Hiero, whose name even yet is given to an interesting machine found in all cabinets of philosophical apparatus, we would be perplexed to find in their writings any statements which could properly be inscribed in modern treatises, and, if we did mention their names it would only be to point out their errors. We see then the reason for the small progress which the ancients made in physics; they only studied it as metaphysics.

The reason they had more success in the study of astronomy was because at an early date they felt the necessity for employing suitable instruments and making observations and calculations.

The happy applications of geometry to one of the most important branches of physics pointed out the road necessary to follow in order to equally perfect all other branches. It was in fact this road which Galileo took at the epoch of the revival of letters and sciences.

It was by geometry that he discovered new and ingenious means for measuring the fall of bodies.

The pendulum, the barometer, the air pump and the prism enlarged the field of experimentation. His book of mathematical principles placed physical science on a true basis. The fact was then fully appreciated that the sciences could be perfected only in so far as they could succeed in carrying into this obscure domain the double torch of experiment and calculation.

S. Gravesende endeavored to produce a complete course of mathematical physics, but magnetism and electricity could find no place in his plan; for electricity was scarcely born and magnetism had been but little developed.

Æpinus was the first who submitted these subjects to analysis. He endeavored principally to explain known effects, but his progress was inconsiderable; for he was not sufficiently careful to verify by experiments the results which he obtained by calculation.

It was by illuminating one fact by another and by fusing them into one, that M. Coulomb reached the hitherto unknown principles with which he enriched physics.

From the first he appreciated the necessity for new apparatus. Attractions, either electric or magnetic, so powerful at exceedingly small distances, either rapidly decreased or disappeared entirely at comparatively small increase of such distances. In order to measure them correctly, it was necessary to oppose them to a known force which they could readily overcome; to employ a body so light as to permit the least force to impart to it a sufficiently great movement, under conditions in which

exceedingly small forces could be rigorously measured. M. Coulomb hoped to find such a force in the almost imperceptible resistance a wire offers to a force tending to twist it. He ascertained that this resistance increases uniformly with the amount of torsion given to the wire, or, to speak in scientific language, that the force was proportional to the angle of torsion. He was then in possession of the instrument he so long desired, and it was by this simple means that he discovered the law which had hitherto escaped the researches of physicists.

He showed by simple and convincing experiments that the attractions and repulsions are in the inverse ratio of the square of the distance. This law was immediately adopted by all physicists, most of whom had a presentiment of its truth. Æpinus had often employed this law in some of his calculations, judging it to be the most probable that could be conceived, but he had not been able to discover the means for its demonstration. This glory was reserved for M. Coulomb.

These discoveries accomplished, by means of which he conquered two modern branches of physics, we see M. Coulomb employing the rest of his life in cultivating the domain he had conquered.

The law which he had discovered became of great assistance in his subsequent calculations and experiments. But it was not sufficient. It would be necessary to combine with it an intimate knowledge of the essential properties of that marvellous agency, the production of which we cannot yet entirely control. Æpinus explained the principal phenomena of electricity and magnetism on the assumption of the existence of a fluid, the molecules of which possessed the double property of mutually repelling one another, and of being attracted by the molecules of gross matter. But he was obliged to assign to these molecules the double property of mutually repelling one another and yet of being attracted by the molecules of other bodies, a property difficult to reconcile with generally received notions.

The hypothesis of a double electric fluid conceived by

Symmer, and employed by Wilke and Brougman, though less simple at first glance, nevertheless contains nothing inconsistent with well-known principles. In all his calculations M. Coulomb adopted this hypothesis as the best.

In order to place this hypothesis beyond all objection, and entirely to reconcile it to the phenomena of attractions and repulsions which it describes, it is very desirable that one should be able, by direct experiments, to demonstrate the existence of these two still problematical electric fluids. They are now indicated only by calculation. They can explain phenomena, but nothing yet demonstrates that it is impossible to find a simpler explanation of such phenomena.

When the early astronomers wished to account for the unequal movements of the sun they found two hypotheses equally capable of satisfying their observations. The double inequality in the movements of the planets requires the assumption of two hypotheses, either of which sufficed to account for the orbits of the very eccentric planets, such as Mars and Mercury. This system, which at first seemed so happily conceived, was afterwards set aside or reversed by Copernicus and Kepler.

One might fear, or indeed, rather desire, a similar fate for our two hypothetical fluids. Already we feel that the phenomena in question require further explanation. To avoid this difficulty, M. Coulomb supposes that all the molecules in a magnetized bar consist of so many magnetized parts, the opposite poles of which are in contact. The opposite actions of these poles should for the greater part destroy each other. The two extreme poles can alone act freely and hence form two centres of action placed at the extreme ends of the bar. No matter how ingenious this conjecture may be, it may very closely resemble the hypothesis of epicycles of the ancient astronomers, which possessed no other real merit than to facilitate calculations which will lead to the knowledge of the real causes. It is the same with the two electric fluids. It is very ingeniously assumed that the resinous and vitreous fluids experience unequal resistance in the air. Nothing prevents us from admitting hypotheses provided they are not incompatible with known principles,

only we may regard with regret the complexity of the system. But, in the midst of so many causes which act to obscure the phenomena, it is not astonishing that the explanation loses much of the simplicity that we would desire it to possess. The planets, separated from one another by immense distances and moving through free space, may rigorously follow the law which suffices to explain their almost imperceptible inequalities. But bodies which we hold in our hands, and with which we experiment, are very far from being placed under such favorable circumstances. Where many forces operate it is necessary to include them all in the calculation, so that complex effects would not be reduced to very simple principles. It is not, therefore, the fault of the physicists if their explanations are not characterized by that unity which we are accustomed to find in the problems of astronomy.

But if physicists are thus placed at disadvantages they are recompensed by other considerations which should animate them with courage.

The heavenly bodies revolving at such vast distances from us, only complete their revolutions in times that are more or less considerable, but always very long, and it is only at great intervals that they can come into conditions favorable for the researches of those who wish to explain their movements. The physicist, on the contrary, holds in his hands the objects of his study. He can at will place them in suitable positions, and, if astronomy has required centuries to perfect itself, we can hope that in much less time physicists will be able to reach that certainty and clearness which may reasonably be expected.

Such progress will ultimately crown the work of those, who like M. Coulomb, have not only endeavored to create new apparatus for new research, but who also avail themselves of the infinite resources that may be found in modern analysis.

By means of the torsion balance, which permitted him to measure the feeblest manifestation of magnetism and electricity, he satisfactorily determined the law according to which electricity passes and insensibly disappears, the influ-

ence which produces the effect, the humidity of the air which surrounds the conductor, and the imperfection of the supports by which they are insulated. He showed by delicate experiments that electricity, which is so powerful at the surface of bodies, becomes insensible when we penetrate the interior but slightly, and that magnetism, very feeble through almost the entire length of the needle, possesses strength in but two points near the ends, and sought to discover the law according to which electricity distributes itself along conductors or on globes of different dimensions. What can be the cause of the power possessed by points and the great effect of the electric kite (*cerf volant électrique*). From these difficult speculations, so pleasing to him, he descends to objects of practical utility. It was to obtain a better construction for the compass that he had undertaken his early researches. In proportion as he made sensible progress he endeavored to improve his more important instruments, as, for example, the inclination compass. At this time more or less complete means for producing artificial magnets were in use. By the application of his theory M. Coulomb was enabled to add increased perfection to the best of these methods.

As regards the influence of temperature on magnetism, viz: that the strength of magnetism decreases as the heat increases, he found by very convincing experiments and by the aid of a theorem of M. La Place that it would be necessary to give a needle 700° of heat in order to deprive it entirely of its magnetism.

For a long time iron had been regarded as the only body which is attracted by the magnet. M. Coulomb found some unequivocal signs of attraction in all the bodies he subjected to experiment, from which he believed that he could conclude that magnetism like electricity occurs throughout nature.

This discovery is the last he made. The task of verifying it kept him occupied up to his last moments. We find in his manuscripts some curious experiments from which it would appear that in order to attribute to iron hid in different bodies the degree of magnetism which he had observed,

we must assume that there exists uniformly spread throughout these substances a quantity of iron so considerable that it would not have failed to manifest itself under the investigations of any distinguished chemist who had undertaken to separate or purify the substances on which he had made his experiments. We shall not now study in detail Coulomb's unpublished researches. These cannot yet be properly judged by savants. We feel that this is not the place to give an extensive idea of his works. Besides, such an exposition already exists. All savants can read it in the best and most modern treatises on physics. Coulomb ranks among the first physicists of Europe. He has distinguished himself by creating a new branch of natural science and has presented in the clearest and most methodical manner all the discoveries and theories of his distinguished contemporaries. This extract, which may serve in some respects as a commentary on the doctrine of M. Coulomb, does not prevent us, however, from having recourse to the original writings for a multitude of details necessary for those who may wish to continue the work that was so sadly interrupted by his death.

For a long time it was hoped that M. Coulomb would collect in a complete treatise, in the order in which he had discovered and demonstrated them, the ideas which he had published in his numerous memoirs. His friends often asked for such a work, but the feeble state of his health gave him little hope of its completion. He preferred to add as much as he could to the sum of our knowledge. He left for the bookseller, who was to print the collection, a note as to the order in which he wished his memoirs arranged. Before beginning the printing, it will be necessary to examine his manuscripts, and to transcribe the notes which he added to them, for this will form an interesting sequel to the material which he has himself published.

We have so far presented M. Coulomb as a very distinguished savant. The man himself, however, was no less deserving of commendation; that good sense, that uprightness and severity of principle, which he manifested in all his mathematical researches, were no less strongly evinced in his moral conduct.

Sent to Brittany by the Minister of the Navy, as a Commissioner of the King, to examine some projected canals, he employed all his energy to prevent the adoption of ruinous plans. The province, recognizing that it could not induce him to accept any other mark of its gratitude, bestowed upon him a testimonial, which possessed in his eyes no other merit than that of often recalling to him the recollection of the services he had rendered and of the esteem he had gained. When the revolution came, he resigned all his public positions, among which was that of General Superintendent of the Water Supplies of France and Superintendent of the Fortifications. The first was hereditary in his very distinguished family and would otherwise have passed to his descendants.

Thus relieved of his labors he occupied himself in collecting the remnant of his fortune, of which he was able to save only a very small part. He hoped to find consolation in the Academy and in the continuation of his labors; but the Academy was suppressed. He retained his membership in the Commission of Weights and Measures, but was cut off from this shortly afterwards, and, being obliged to leave Paris by the law which expelled all the nobility, he retired with his friend Borda, to a country seat which he owned, in the neighborhood of Blois.

In this solitude, in the bosom of his family, and with the consolation of friendship, M. Coulomb almost changed the manner of his life. He was able still to continue his meditations, which he even extended to new objects. The vegetable world claimed his attention. Some trees he had cut down gave him ideas on the motion of the sap. He began some researches on plants, and the fragmentary notes on these subjects which we find in some of his manuscripts, make us wish that the remainder was accessible.

Recalled from exile to continue his labors on weights and measures, we find him at this work for but a few days. He was anxious to return to his wife and children and to take care of the little property which was now their sole resource.

He returned to Paris only on the re-establishment of the

Institute. His health, which had been impaired, made it necessary for him to seek that medical aid which he had so long refused. An excessively nervous temperament gave him vivacity of character, coupled with a certain impatience, from which however, owing to his constant endeavor to conquer it, he alone suffered.

Named as an Inspector General of Instruction, although he might have regarded this favor as an indemnification for his many losses, and although by reason of his varied knowledge in different branches of public instruction, he was as well qualified as any person for so important a post, yet he hesitated a long time as to whether he should accept it.

He feared fatigue that would injure his health, as well as protracted absence that would interrupt works in which it would be difficult to find a substitute. He had devoted himself to developing the character of a son, who already responded to his care and whom he would now be obliged to place in other hands. He however, accepted the position offered, Madame Coulomb now became his inseparable companion in all his work. Thanks to her care and to her active tenderness, he escaped the dangers he had feared from his public labors.

M. Coulomb gave himself up to his new duties with all the zeal and precision which characterized him. His grave and severe countenance was softened by the presence of young children, who recalled to his paternal heart its sweetest delight. He spoke to them as a father to his children; aided them in their weaknesses and encouraged them in their timidity. He loved to find, in their growing character, promises of talent which might eventually be of use to his country. Only those who have seen him in private life can properly testify to the charm and abandon of his nature. Faithful husband, kind brother, good father and friend, man of integrity and devoted citizen, he exercised all virtue spontaneously and without ostentation; severe to himself but indulgent toward others. His manner exhibited that ease which comported so well with the gravity of his character, but which could not suppress his

sweet and quiet gaiety which was that of a soul at peace with itself. Noble and generous in all his affairs, he occupied himself least of all with his own interests.

Although modest and unpretentious, he knew how to repel an unjust attack with both strength and dignity. This last trait of his character he had but little occasion to develop. In the one case which comes to our knowledge, and which the Institute has not forgotten, his adversary who did not know that he was attacking M. Coulomb, afterward admitted his own error.

No one enjoyed more general consideration. He had seen his doctrine admitted and taught by the most distinguished scientific men. The world was pleased to render him justice. His merit and his success never made him an enemy. He longed for nothing but better health. His condition, for a long time before his death, gave his friends much uneasiness. A grave chronic infirmity, which he himself regarded as the forerunner of approaching death, was added a slow fever which gradually consumed him.

The feeble condition to which he was reduced, forbade him taking any nourishment; and all resources of art, administered by hands of friendship, were found equally powerless to mitigate his suffering or to revive his failing strength. He died on the twenty-third of August, 1806, leaving to his son no other inheritance than his honored name, the example of his virtues and the memory of the important services which he had rendered to the world.

His place in the Academy was filled by M. Montgolfier.

Certified and confirmed by the Perpetual Secretary of the Section of Science and Mathematics. F. ARAGO.

Section of Engineers and Naval Architects

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the Preliminary Meeting of the Penn Institute of Engineers and Naval Architects as a Section of the Franklin Institute, September 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 21, 1893.

MR. WM. H. BARGER, in the chair.

The Chairman appointed Mr. Newman Secretary for the evening.

Members present—Messrs. Barger, Yeo, Cresswell, Sicord, Quinn, Lovekin, Nilson, Newman, Helstrom.

Members absent—Messrs. Folmer, McLaughlin, Campbell, Ham, Pistor, Hartley, Matlack, Branson.

The Chairman stated that the gentlemen above-named as forming the Penn Institute of Engineers and Naval Architects, individually members of the Franklin Institute, had as a body made application for permission to form a Section of the Franklin Institute, to be known as the Section of Engineers and Naval Architects; that the application had been granted, and that the object of the meeting was to fix upon an evening for holding the monthly meetings and to elect officers.

He also stated that he had interviewed Dr. Wahl, the Secretary of the Institute, and had been informed that the most suitable evening would be the fourth Wednesday of each month.

It was thereupon resolved to hold the monthly meeting on that evening.

Resolved; that as the meeting consists of a majority of the members, it do now proceed to elect officers.

The following officers were then elected:

President—R. L. Newman.

Vice-Presidents—Wm. H. Barger, Andrew Ham, Wm. F. Sicord.

Recorder—Robert McLaughlin.

Treasurer—Alexander Campbell.

Corresponding Secretary—John F. Quinn.

Conservator—George S. Yeo.

The Chairman appointed the following gentlemen a committee to draft a set of by-laws for the government of the Section: Messrs. Campbell, Barger, Ham, Sicord, Folmer.

It was then resolved that the first regular meeting of the Section be held on the fourth Wednesday in October.

The meeting then adjourned. R. L. NEWMAN, *Secretary pro tem.*

[*Proceedings of the stated meeting, held Wednesday, October 25, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 25, 1893.

Mr. R. L. NEWMAN, President, in the chair.

The first stated meeting of the Section of Engineers and Naval Architects was held this evening.

The minutes of the preliminary meeting were read and approved.

The President having announced the unavoidable absence of the Recording Secretary, Mr. Campbell kindly volunteered to perform his duties for the evening.

The following gentlemen were proposed and duly elected to membership:

Messrs. Edwin S. Cramp, Lewis C. Nixon, James H. Horgan, Walter S. Cramp, J. W. Atlee, James Young, Nesbit Sinclair, G. L. Davidson, E. C. Given, E. Heyne, E. Hoel, C. Heinrichs, Nelsen Madsen, Wm. Collison, Wm. H. Wahl, John McInnes, John McMaster, John A. Nilson, Thos. Jarvis, John Sullivan, James B. Rowen, Wm. J. Warne, Leighton Lee, W. K. Watson, Albert Duboy, E. L. Peacock, John Bayne, Jr., Henry Pemberton, Jr., F. L. Gamson, R. D. Wilson, C. B. Schultz.

This being the first regular meeting of the Section, the President delivered his inaugural address, in which he dwelt upon the foundation of the Section, its aims and its prospects for the future.

The by-laws were then read, and Articles 8, 11, 13 and 14 amended.

The Section unanimously accorded a vote of thanks to Dr. Wahl, Secretary of the Institute, for his kindness in being present and for his assistance in formulating the by-laws.

Mr. Barger was accorded a vote of thanks for the energy he displayed in bringing the members together for this evening's meeting.

Attendance, thirty-three persons, including visitors.

The meeting then adjourned.

ALEX. CAMPBELL, *Secretary pro tem.*

[*Proceedings of the stated meeting, held Wednesday, November 22, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 22, 1893.

Mr. R. L. NEWMAN, President, in the chair.

The second stated meeting of the Section of Engineers and Naval Architects was held this evening.

The minutes of the previous meeting were read and approved.

The by-laws were read, with amendments made at previous meeting, and unanimously adopted.

The following-named gentlemen were proposed for membership and duly elected: Messrs. August Bod, J. V. Olsen, Jas. S. Doran, Wm. C. Foley, Thomas Jordine, Walter Whetstone, A. Masters, James C. Workman.

A paper on "The Subdivision of Steamships" was read by Mr. Andrew Ham.

An animated and instructive discussion followed the reading of Mr. Ham's paper, and was participated in by Messrs. Foley, McInnes, Stoever, Warne, Newman and Campbell.

Attendance, thirty-six persons, including visitors.

Adjourned. ROBERT MCLAUGHLIN, *Secretary.*

SECTION OF ENGINEERS AND NAVAL ARCHITECTS.

THE PRESIDENT'S INAUGURAL ADDRESS.

[*Read at the first stated meeting of the Section, held Wednesday, October 25, 1893.*]

MR. RICHARD L. NEWMAN, President, in the chair.

On assuming the chair, the President spoke as follows:

GENTLEMEN:—I take this opportunity of expressing to you my thanks for the honor you have done me in electing me your first President.

It will be my earnest endeavor during this session to promote the best interests of this Section, and, as one of its founders, I am the more anxious to see it a complete success. I trust that both the officers, and all our friends who have its welfare at heart, will support me in my endeavor to this end. I hope, therefore, that they will attend regularly at our various meetings, and thus, by their presence, encourage the contributors of papers and give to this Section (and especially to the younger members of the same) the benefit of their experience and advice. For I consider that the great feature of societies like our own is the discussion of subjects, rather than the mere listening to a paper or a lecture.

I also trust that many of our younger members will join in these discussions, both for the sake of eliciting information from those who can give it, and to show that they take an interest in the subject under discussion. A good way of learning something of a subject, is to criticise it in a proper spirit, and any young member who will get up the

necessary information to properly criticise such papers as may be read here, will find, at the end of the session, that he has gained considerable information.

I must also congratulate you on your good fortune in starting as a Section of one of the oldest scientific societies in America, if not the very oldest.

Here you have a good and permanent home and the use of one of the most complete scientific libraries in the country. The advantages of the latter must be plain to all, as it brings within the reach of those of our members who desire to prepare themselves for our future discussions, such books as would otherwise be difficult to obtain.

As to our financial position I can say but little; but I would call your attention to the necessity of accumulating funds in the early days of a society like this for its successful career afterwards—for the day must come when, to continue with success, we shall have to expend considerable sums of money; and, to enable us to do so, I would recommend economy until such time as we consider ourselves on a sound financial basis.

Another point that I would particularly draw your attention to, is this: that those of our members who are willing to provide us with papers during the present session, would greatly facilitate our arrangements by notifying the Secretary as to the subject they desire to write on, and the earliest date at which they can deliver the paper to the Secretary to enable him to arrange a syllabus of our future work. We have already received promises of papers from Mr. Walter Cramp, Mr. Campbell, Mr. Peacock, Mr. Blumberg, and several other gentlemen.

Although at one time it appeared as if mechanical engineering and ship-building had a limit to which we were fast approaching, and that sooner or later all that could be known, or was worth knowing, would become known, yet, as time goes on, we are found branching out right and left on new departures. We find that, so far from having reached the length of our scientific tether, completely new fields have been opened up. During the last eight years

the marine engine has undergone another change somewhat similar to that which it passed through some twenty to twenty-five years ago. The result of this has been further economy of fuel, and although not so startling as in changing to the first compound, yet the gain was sufficiently tangible to justify engineers in their new departure, and it has been the means of inducing men, in their hunt for a remunerative investment, to spend their money with the engineer and ship-builder. We are, I think, now at a stand-still, as far as the engine is concerned, and are likely to remain so for some time to come. It is true that we have the quadruple engine, but I think the gain, or economy, here is more apparent than real, and is likely to remain so until such time as we are in a position to command and work much higher steam pressure than we now have.

The next advance will, I think, be made in the boiler, in the apparatus in which the agent is generated for propelling the machinery. Whether it will be a steam boiler or not I cannot say; but when we look round and realize with what an extravagant hand we draw on the bountiful resources of nature, it is then, and only then, that we see the necessity for a saving in this direction. Can anyone imagine anything more crude than our modern boiler? I grant you that it has been created by the surmounting of a series of difficulties that only an engineer can appreciate; but I am now dealing with the machine as viewed from a scientific standpoint, and I am sure you will all agree with me that when we put under a boiler a certain quantity of coal, representing theoretically a given quantity of work and in return get between 0·5 and 0·7 of this theoretic value, it is then time for us to look round for another agent or a more economical method of developing the present.

Gentlemen, it is one of the easiest things in the world to find fault; but it has been my experience that it is one of the most difficult to find a remedy.

Here we are, finding fault with a very old friend, but we shall have to stick to him, or improve him, until we can find a better.

I think the future march of improvement should be

looked for in the development of the multitubular boiler, induced or improved forced draught, and the adoption of petroleum as a fuel.

In the first case, we may be able to get a boiler to generate steam at say 500 or 600 pounds per square inch, thereby increasing the indicated horse-power per ton of boiler. But it might be urged that we could not handle steam at such a pressure and temperature. Admitting this to be a fact, I am still of opinion that it would pay us to reduce the pressure to about 300 pounds, thereby superheating it and raising its efficiency.

Induced Draught.—One of the most pronounced losses of the modern boiler lies in the fact, that to obtain a good combustion you have to maintain a smoke-pipe temperature of say 600° F. This heat, apart from the fact of its maintaining a good draught, is completely lost, so far as the generation of steam is concerned. With induced draught this factor becomes eliminated, as the smoke-pipe temperature is then of small importance. You could therefore absorb this heat by passing it first through a superheater and then through a large feed heater; raising your feed, probably, to the temperature of the boiler. The only work the boiler would then have to do would be to supply the heat necessary to set the vapor free, or what is known as the latent heat.

Mr. Howden claims by his plan to have effected an economy approaching the marvellous. That the figures he published are accurate is to be doubted; but that the results he obtained are satisfactory is beyond question; and there can be no doubt whatever that by heating the air supplied to the furnace by means of the waste heat of the chimney, and by forcing it into the furnace under a pressure equal to one inch of water, a more perfect and complete combustion can be obtained than by ordinary conditions, and that the economy resulting therefrom must be considerable. There still remains the fact, however, that even with this system a quantity of heat, somewhat less to be sure than would be under natural conditions, still goes off into the atmosphere, owing to the very limited capacity of air to absorb heat.

Scientific engineers are, however, looking beyond the mere question of how best to burn coals. They are looking to what may be termed the fuel of the future; that is, petroleum or natural oil. This valuable material is being found in all parts of the world, and the only thing that astonishes me is that its introduction is so slow. Russian steamers on the Volga and Caspian have long used, with the utmost success, the waste products resulting from the manufacture of petroleum.

Weight for weight, this refuse is capable of producing twice as much steam as coal can produce. It is easily stored, and practically occupies less space than does coal; it emits no smoke; it is easily regulated, and it requires the least possible amount of attention.

Here then is a picture for us engineers to contemplate. Imagine the *Lucania* fitted up with a series of multitubular boilers, with a system of feed heating reducing the smoke-pipe temperature to a minimum and raising the feed-water to a temperature equivalent to that of the boiler, and using petroleum as a fuel. Now, here would undoubtedly result a saving in weight carried, for one ton of oil alone is about equal in effect to two tons of coal, and the weight of the boilers would be reduced. There would also be a considerable saving in the cost of labor for running the machinery, and, assuming the cost of creosote per ton to be about the same as coals, the fuel bill would be reduced by about one-half. Taking the amount thus saved in weight and cost, and expending it in larger and more powerful machinery, I see no reason why, in the near future, with a properly constructed ship, we should not cross the Atlantic at an average speed of twenty-five knots or more.

Progress in ship-building is not of necessity so rapid as that in engineering, and is seldom marked by radical departures. We find perhaps some one with more enterprise than his neighbors who will build a larger and faster vessel than usual; but a ship of a new form or of new material is seldom heard of. We do find, however, that although the forms change but slowly, and although the materials of which they are built remain practically the same, the speed of our

ocean-going steamships is steadily advancing, viz: from eighteen to nineteen and twenty knots per hour.

We have seen the steam launch of seven and eight knots develop into the torpedo boat of twenty and twenty-five knots per hour. But the mercantile cargo boat of to-day is of pretty much the same character as was her predecessor of twelve years ago.

That the electric light has taken fast hold of the mercantile and of the naval marine is not to be wondered at. Its safety, cleanliness and absence of smell and of foul air is of the utmost advantage to those whose home is limited to a narrow cabin; the long nights are thus deprived of one-half their wearisomeness and terror to the passenger by its means. The convenience of being able to start mast head-lights and side lights by the mere turning of three small buttons is apparent. In the engine-room it lightens the monotony of the weary watcher and enables him to make use of his eyes to a much greater extent than is possible with the ordinary means of illumination.

Steel castings can now be had of any size, form or weight, and it is price alone that prevents their complete substitution for iron ones; but that energy and enterprise which have enabled our manufacturers to provide us with steel plates at such a price as to supersede those of iron, will, I have no doubt, surmount their present difficulties, and I am confident that we may safely look forward to the time when we shall get steel castings at such a price as will enable them to supersede cast iron for most purposes.

The commercial depression has, I hope, reached its lowest point, and there are now signs, I am glad to say, of its lifting and, I hope, eventually disappearing. When the dawn of prosperity breaks upon the ship-owner, we may hope that the ship-builder and engineer will soon feel the effects of it, and that once more our now idle machinery may be supplied with work, and busy brains find remunerative employment.

This address would hardly be deemed complete without some slight allusion, however incomplete, to the most colossal undertaking of the present century, namely, the World's

Fair. Here we have a collection of machinery the like of which have never before been seen under one roof. Electric generators of 2,000 horse-power, the Ferris wheel, the buildings themselves, all are triumphs of engineering skill.

From a spectacular point of view it stands unrivalled. The Rev. W. H. Stead, in his description, speaks of it as follows: "I have seen no picture of the abode of the blest which comes near to it in its serenity, its suggestion of the invisible holiness, its atmosphere of bliss. That it would have given 'points' to the writer of Revelations, had he seen it, was a remark which scarcely seemed profane in the presence of that mystic spectacle. Precious stones do not appeal to us Westerners as they do to Orientals, and for my part I prefer the white glory of the Hellenic architecture, transfigured by the electric light, to the blaze of all the jewels with which the gorgeous imagination of the East could deck the battlements or pave the streets of Paradise. Until I see the walls of the New Jerusalem itself, I never expect to see a dream of more exquisite loveliness than this."

I trust I have not wearied your patience by travelling over so much ground. I have given you many subjects for reflection, and, I hope, not a few on which you may favor us with a paper, and I trust that the session, as regards the number and interest of the papers that will be read, may be a success.

BOOK NOTICES.

The Chronicle Fire Tables for 1893. A record of the fire losses in the United States by States and Territories during 1892, etc. New York: The Chronicle Company, Limited. (Price, $5.)

This valuable and extensive collection of fire data (now in its eighteenth year) presents its last annual tabulations in 360 pages, royal 8vo, with the usual excellence in all respects. The need for this kind of information, especially to fire insurance companies, was never more evident than now, when the fire losses in the United States during 1890, 1891 and 1892 are shown to have been, respectively, $100,000,000, $144,000,000 and $151,500,000. The situation is becoming every year more serious and alarming. The plan of the work insures accuracy, as nearly as attainable, and since adjustments and estimates of losses are obtained always several weeks after occurrence of fires, exaggeration of losses is avoided.

The work opens with general information respecting the fires, and an analysis of causes, referring in detail to the most important, while showing the distribution of losses in the geographical divisions, also the average loss per fire, losses by exposure during the past eight years and fires caused by electric wires or lights in the period 1885–92, inclusive. The last-named cause is shown to have increased the losses from $254,595 in 1885, to $2,966,536 in 1892. The main tabulation gives an alphabetical list of classes of risks, ranging from agricultural implement factories to whalebone and rattan factories, including warehouses of various kinds, separately stated. Here are given, besides the name of the class, the number of fires, property loss, insurance loss and the causes of fire, with number of fires to each cause.

Similar tabulations show the fire losses in each State and Territory during 1892, also by classes of risks. Another extensive analysis shows the fires by causes, such as accidents, ashes, hot coals, with the number of exposures, property loss, insurance loss, insurance loss by exposure and the character of the property burned. This is much like a reversal of the main tabulation, giving views from a different standpoint, thus emphasizing the information. There is, at p. 247, a *summary* of losses from all causes in detail, followed by a showing of the various risks burned in the United States in the eighteen years, 1875–92, by principal classes; then monthly losses by fires in 1892, and much other fire data which we have not space to mention.

This admirable work shows no diminution of its remarkable energy, clearness and evident correctness. No fire insurance company should be without it, nor any lawyer, for the latter have frequently to manage cases influenced by fires. It is generally believed (whether correctly we cannot say) that times of financial stringency cause a large increase of incendiary fires. To appreciate rightly this cause of fires and its extent, is now of much importance to legal and business men.

The *Chronicle Fire Tables* form a wonderful compendium of fire data, without an equal in the world; and as a condensed history of fire losses and causes of fire during the past eighteen years (and to be continued for all coming time, let us hope), its value to society and general business is simply incalculable. N.

Continuous Current Dynamos and Motors: Their Theory, Design and Testing. With sections on Indicator Diagrams, Properties of Saturated Steam, Belting Calculations, etc. An Elementary Treatise for Students. By Frank P. Cox, B.S. New York: The W. J. Johnston Company, Limited, 41 Park Row (*Times* Building). 1893. 271 pages. Eighty-three illustrations. (Price, $2.)

This work, intended for students, treats of the theory of continuous current dynamos and motors as understood and practised in the designing room, and the methods of testing described are those of the factory testing room. The practical side of various questions treated is always kept in view, discussions having little bearing in this direction being excluded, as are also the descriptions of different machines and systems which are occasionally used as padding to fill out the pages of similar treatises.

The first four chapters present a brief review of the electrical units and the general principles of the machines, and may be considered as an introduction to the subsequent portions; the higher branches of mathematics have been avoided here, as elsewhere. Chapter V is on calculations pertaining to the magnetic circuit. Chapter VI treats of the theory of windings, losses, etc., and Chapter VII of the special points to be observed in designing motors.

In Chapters VIII, IX and X, the application of the principles developed in the preceding chapters to the design of armatures, field magnets and motors, is explained by reference to numerical problems selected with the object of covering as broad a field as possible, and of showing in what manner to make the various compromises always found expedient or necessary in practical designing.

In Chapter XI and XII, the methods of testing completed machines and investigating their characteristics and the effect of various changes in design and operation are fully discussed and illustrated by numerous curves.

As the steam engine, and its efficiency have an ultimate relation to the efficient operation of dynamos and motors, the last two chapters are devoted to the subjects of indicator diagrams and steam-power calculations, which are treated in the same eminently practical manner as the electrical portion of the work. There are four appendices treating of physical tests of irons, ampère time tables, determinations of sizes of wire for armatures and field coils, and on the calculation of belt driving.

The engravings appear to be new, and nearly all of the numerous curves are said to be reproductions of those obtained in actual commercial tests. The book is a valuable addition to electrical literature. W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 15, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 15, 1893.

Mr. JOSEPH M. WILSON, President, in the chair.

Present, 126 members and twenty-four visitors.

Additions to membership since last report, twenty-four.

The Actuary reported the following resolution, adopted at the stated meeting of the Board of Managers, held Wednesday, November 8, 1893, viz:

Resolved; that in view of the facts, that the general feeling of those who have been spoken to on the subject is that the probability of a financially successful exhibition being held at the present time is doubtful, and that the Institute in its present financial condition can assume no risks, and would therefore be obliged to obtain a large guaranty fund to guard it against loss, which fund, in the present depressed condition of business, it is feared, would be very difficult to obtain; and, further, that the question

of location and buildings essential for success forms a serious obstacle—therefore, it is the sense of the Board that it is not advisable to attempt to hold an exhibition in the year 1894.

The resolution was accepted.

Mr. C. John Hexamer concluded his descriptive account of the World's Fair.

Mr. David Branson read a paper on the subject of "Refrigeration from Central Stations," with special reference to the system of the International Cooling Company of New York, which has been for several years in successful operation in the cities of Denver, Col., and St. Louis, Mo. The paper was illustrated by a number of lantern views, exhibiting the details of the pipe line, service pipes, interior distribution, etc. (Referred for publication.)

The Secretary read a brief paper, communicated from London, England, by Mr. F. E. Ives, discussing the claims and merits of certain improvements made by the brothers Lumière on Professor Lippmann's method of color photography. (Referred for publication.)

The Secretary, in his monthly report, apropos to Mr. Ives' paper, gave some account of recent progress that had been made in the solution of the problem of photography in color. He referred also to the admirable record made by the Intramural Elevated Electric Railway in the World's Fair grounds. This road, under conditions of extreme severity, had given smooth, regular and punctual service during the entire period of the Fair, during which time it had carried more than 6,000,000 paying passengers without a single accident. While the data of the cost of its operation were not yet available, he believed that it would compare very favorably with those of the elevated steam roads in New York and elsewhere, while in respect of freedom from smoke, and the dropping of ashes, sparks and oil, it exhibited decided superiority.

Under the head of new business, the question of the advisability of holding an exhibition of type-writing machines was, on Mr. Eldridge's motion, referred to the Board of Managers for consideration.

Adjourned. WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

H. L. BALL, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR JULY, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, July 31, 1893.

GENERAL REMARKS.

The normal temperature of Pennsylvania for July is about 72°·9, and the normal rainfall 4·27 inches.

The temperature of July, 1893, was only slightly below the normal, taking the State as a whole. The eastern portion of the State was apparently slightly warmer than that west of the mountains. At Philadelphia and York the total excess for the month was 15° and 61° respectively. The latter is probably a little too high owing to the fact that the "normals" for York are compiled from but five years of records. At Pittsburgh and Erie there was a total deficiency, for the month, of 42° and 27° respectively.

The warmest weather occurred on the 25th and 26th. Cool weather immediately preceded and followed this warm spell, and most of the low temperatures were recorded on the 24th and 28th. The most marked change in temperature occurred on the 25th, as on that day most stations recorded their greatest daily range.

The monthly rainfall was below the normal at nearly all the stations, and especially deficient in the lower Susquehanna and Lake basins. It was above the normal at a few western stations. A protracted and serious drouth set in during the last decade, and by the close of the month rain was badly needed in all sections.

The deficiency in rainfall for the month at Philadelphia was 2·49, at York 4·10, and at Harrisburg 2·32 inches, that of York being probably too great owing to the normals having been obtained from but five years of records. At Pittsburgh the monthly deficiency was not so great, the former stations having a deficiency of 0·23 and the latter 1·11 inches.

From January 1, 1893, to July 31, 1893, the deficiency in temperature at Philadelphia was 318°, at Erie 3.59°, and at Pittsburgh 362°.

For the same period the deficiency in precipitation at Philadelphia was 0·91 at Erie an excess of 3·69 and at Pittsburgh 2·22 inches.

	Mean Temperature.	*Mean Precipitation. Inches.*
July, 1888,	69°·4	3·45
1889,	71°·2	6·80
1890,	70°·8	3·52
1891,	67°·9	6·32
1892,	72°·0	3·93
1893,	72°·0	3·15

TEMPERATURE.

The mean temperature for July, 1893, was 72°·0, which is about 0°·9 below the normal, and the same as the corresponding month of 1892.

The mean of the daily maximum and minimum temperatures, 84°·2 and 60°·0, gives a monthly mean of 72°·1, with an average daily range of 24°·2.

Highest monthly mean, 77°·0 at Philadelphia. [Weather Bureau.]

Lowest monthly mean, 65°·1 at Wellsboro.

Highest temperature recorded during the month, 102° on the 26th at Aqueduct and Quakertown.

Lowest temperature, 36° on the 24th at Wellsboro.

Greatest local monthly range, 60°·0 at Lewisburg.

Least local monthly range, 36°·0 at Philadelphia. [Weather Bureau.]

Greatest daily range, 49°·0 at Lock Haven on the 30th.

Least daily range, 3°·0 at Hamburg on the 14th.

BAROMETER.

The mean pressure for the month, 29·98, is about ·02 inch above the normal. At the United States Weather Bureau Stations, the highest observed was 30·25 at Philadelphia on the 11th, and Harrisburg on the 28th, and the lowest 29·68 at Philadelphia on the 22d.

PRECIPITATION.

The average rainfall, 3·15 inches for the month, is a deficiency of about 1·12 inches.

The largest monthly totals in inches were Clarion, 6·27; Immel Reservoir (Lycippus), 6·36; Ligonier, 6·21 inches.

The least were York, 1·58; Erie and Warren, 1·79; Harrisburg, 1·92; Coopersburg, 1·96; Pottstown, 1·99 inches.

WIND AND WEATHER.

The prevailing direction of wind was from the West.

Average number: rainy days, 10; clear days, 15; fair days, 12; cloudy days, 4.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 3d, 5th, 6th, 7th, 8th, 13th, 14th, 15th, 16th, 17th, 18th, 26th, 29th, 31st; Hollidaysburg, 7th, 13th, 15th, 17th, 26th; Wysox, 22; Le Roy, 3d, 15th, 18th, 26th; Forks of Neshaminy, 3d, 5th, 8th, 16th, 17th, 18th, 26th; Quakertown, 3d, 5th, 8th, 13th, 16th; Johnstown, 3d, 5th, 6th, 8th, 13th, 14th, 26th; Emporium, 3d, 8th, 15th, 26th; East Mauch Chunk, 3d; State College, 5th, 8th, 13th, 15th; West Chester, 3d, 8th, 18th, 26th; Coatesville, 3d, 5th, 8th, 13th, 16th, 17th, 18th, 26th, 29th; Kennett Square, 3d, 8th, 13th, 26th; Phœnixville, 3d, 5th, 8th, 13th, 16th, 26th; Lock Haven, 3d, 8th, 13th, 15th, 17th, 23d, 26th, 29th; Bloomsburg, 8th, 13th, 16th, 29th; Meadville, 3d, 6th, 8th, 15th, 17th, 22d; Saegertown, 3d, 8th, 17th; Carlisle, 5th, 6th, 7th, 8th, 15th, 31st; Harrisburg, 5th, 13th, 15, 26th; Edinboro, 2d, 5th, 6th, 8th, 13th, 22d; Chambersburg, 6th, 8th, 13th, 26th, 31st, Huntingdon, 7th, 13th, 14th, 15th; Kilmer, 3d, 5th, 8th, 13th, 15th; New Castle, 26th; Lebanon, 3d, 5th, 8th, 23d, 26th; Coopersburg, 3d, 5th, 8th, 29th; Drifton, 9th, 13th, 15th, 26th; Wilkes-Barre, 3d, 8th, 13th, 15th, 18th, 23d, 29th; Smethport, 3d, 6th, 8th, 15th, 22d; Pottstown, 3d, 5th, 8th, 13th, 16th, 26th; Easton, 3d, 5th, 6th, 8th, 13th, 15th, 16th, 26th; Aqueduct, 3d, 4th, 5th, 7th, 8th, 13th, 15th 23d, 26th; Philadelphia (Weather Bureau), 3d, 5th, 8th, 13th, 16th, 17th, 18th, 26th; (Centennial Avenue), 3d, 5th, 8th, 13th, 16th, 17th, 18th, 26th; Blooming Grove, 3d, 5th, 8th, 12th, 22d, 26th; Girardville, 3d, 5th, 13th, 15th, 16th; Selins Grove, 8th, 13th, 16th, 29th; Somerset, 7th, 8th, 13th, 15th, 26th; Wellsboro, 3d, 5th, 8th, 13th, 15th, 22d, 26th; Dyberry, 3d, 5th, 8th, 12th, 18th, 22d, 26th; Salem Corners, 3d, 8th, 12th, 13th, 15th, 18th, 22d, 26th; South Eaton, 2d, 3d, 5th, 8th, 13th, 18th, 26th; York, 3d, 5th, 8th, 13th, 26th, 31st.

Hail.—Phœnixville, 5th; Edinboro, 17th; Lebanon, 3d, 5th; Pottstown, 5th; Aqueduct, 3d; Philadelphia (Weather Bureau), 5th; (Centennial Avenue), 5th; Girardville, 3d; Somerset, 13th; Wellsboro, 22d.

Frost.—Smethport, 24th; Somerset, 24th; Wellsboro, 11th, 24th.

Aurora.—Coatesville, 15th, 19th; Carlisle, 15th; Salem Corners, 16th, 17th, 18th.

Coronæ.—Blue Knob, 20th, 23d, 25th, 28th.

Lunar Halo.—Blue Knob, 23d.

Meteors.—Quakertown, 17th; State College, 28th.

Date.	Relative Humidity.
8, 29	63·6
14	. .
. . .	. .
22	. .
29	. .
29	. .
15	79·7
9	. .
. . .	. .
14	73·7
9	. .
14, 17	84·2
14	. .
9	71·4
14	67·0
14	. .
. . .	. .
14	69·0
. . .	. .
9, 17	. .
14	. .
14, 15	88·9
29	. .
29	. . .
14	. . .
14	67·0
. . .	. . .
. . .	. . .
9	66·0
. . .	. .
27	. . .
23	69·3
3	. . .
. . .	. . .
. . .	. . .
. . .	. . .
8	. . .
14	79·0
14	. . .
14	71·0
15	. . .
26, 27	. . .
14	69·3
. . .	. . .
14	. . .
. . .	. . .
14	64·0
14	67·3
. . .	. . .
. . .	. . .
14	. .
29	. . .
13	. .
. . .	. . .
15, 22	86·5
. . .	. . .
15	. . .
14	. . .
3	. . .
. . .	. . .
31	. . .
14	. . .
14	75·5

8 + ÷ 2. [3] M

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for July, 1893.

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level. Mean.	Highest.	Lowest.	Temperature. Mean.	Maximum. Highest.	Date.	Minimum. Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Greatest.	Date.	Least.	Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
Allegheny,	Pittsburgh, A,	820	29'99	30'22	29'78	74'0	95	25	53	11	84'9	62'5	22'4	32	28	15	8, 29	63'6	60'0	5'08	...	...	12	15	14	2	NW	NW	NW	O. D. Stewart, Weather Bureau
Berks,	Hamburg,	380	...	...	...	74'3	97	13	50	24	87'1	61'5	25'6	41	25	3	14	...	...	3'34	...	...	6	3	22	6	NW	...	...	William Shipe
Ferks,	Reading, A,	280	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2'91	...	...	...	...	...	...	...	...	...	Franklin Yager
Blair,	Altoona, B (30 days),	1,181	...	...	...	75'9	95	8, 9	54	1	86'1	65'6	20'5	30	27	12	22	...	...	2'50	...	...	8	...	...	...	...	...	...	Dr. C. B. Dudley
Blair,	Blue Knob, A,	2,500	...	...	...	70'5	90	14	52	10, 24	79'0	62'0	17'0	33	25	8	29	...	...	3'70	...	...	11	10	18	3	NW	NW	NW	A. H. Boyle
Blair,	Hollidaysburg,[4]	947	...	...	...	71'8	94	6, 8	41	28	87'5	54'0	33'5	44	28	22	29	...	...	2'26	...	...	7	18	11	2	W	W	W	Prof. J. A. Stewart.
Bradford,	Wysox[1],	718	29'98	30'27	29'71	70'2	92	25	41	24	82'7	56'4	26'3	42	29	15	15	79'7	63'0	3'98	...	...	9	17	5	9	NW	NW	NW	Charles Beecher
Bradford,	Le Roy,	1,400	...	...	...	69'8	91	8, 25	46	24	80'2	59'4	20'8	37	25	9	9	...	...	2'18	...	...	12	14	16	1	SW	SW	SW	G. W. T. Warburton
Bucks,	Forks of Neshaminy[1] (29 days),	304	...	...	...	74'3	...	...	...	...	...	...	...	...	...	...	...	...	...	1'56	...	...	9	19	4	6	W	W	E	J. C. Hilsman.
Bucks,	Quakertown,[1]	536	29'97	30'27	29'76	72'0	102	26	46	28	86'5	60'2	26'3	37	22	9	14	73'7	60'6	2'25	...	...	10	12	15	4	SW	SW	SW	J. L. Heacock.
Cambria,	Johnstown, A,	1,184	30'01	30'25	29'81	72'1	96	25	47	11, 28	85'8	58'4	27'4	44	25	14	9	...	...	2'81	...	...	15	8	19	4	S	...	S	E. C. Lorentz.
Cameron,	Emporium, A,	1,050	29'99	30'32	29'71	70'1	92	15	45	11	82'9	57'1	25'8	35	11, 25	17	14, 17	84'2	62'1	2'37	...	...	10	16	12	3	W	...	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	...	...	...	70'9	94	13, 26	46	28	84'3	57'5	26'8	42	25	5	14	...	...	3'26	...	...	7	24	3	4	W	W	W	F. C. Wintermute
Centre,	State College[1]—																													
	Agricultural Experiment Station,	1,191	29'94	30'21	29'70	70'6	91	25	47	24	81'3	58'3	23'0	34	25	14	9	71'4	60'8	4'10	...	...	11	11	15	5	W	W	W	Prof. Wm. Frear.
Chester,	West Chester,[1]	455	29'97	30'22	29'67	73'9	94	26	54	24, 28	83'7	65'0	18'7	29	25	6	14	67'0	62'3	2'60	...	...	12	21	5	5	NW	W, NW	S	J. C. Green, D.D.S.
Chester,	Coatesville,[1]	380	...	...	...	73'6	96	26	51	25	85'7	62'2	23'5	39	25	6	14	...	...	2'70	...	...	12	17	10	4	W	W	W	W. T. Gordon.
Chester	Kennett Square, A,[2]	275	...	...	...	72'4	80	25	61	24	...	...	...	...	...	...	...	...	...	2'52	...	...	12	16	13	2	S	...	SW	B. P. Kirk
Chester,	Phœnixville, A,	190	29'98	30'26	29'68	75'3	98	20	52	28	86'0	64'6	21'4	36	25	9	14	69'0	63'6	2'81	...	...	13	15	7	9	NW	...	NW	Knowles Croskey.
Chester,	Westtown,	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Harry Alger.
Clearfield,	Grampian,*[1]	1,450	...	...	...	70'4	94	9	54	11, 24	82'6	61'8	20'8	32	12, 25	14	9, 17	...	...	4'21	...	...	11	7	19	5	SW	SW	W	Nathan Moore
Clinton,	Lock Haven,[1]	560	...	...	...	71'6	96	25	40	28	88'5	56'5	32'0	49	30	17	14	...	...	3'34	...	...	11	20	8	3	W	W	W	Prof. J. A. Robb
Columbia,	Bloomsburg, A—																													
	State Normal School,	500	...	...	...	75'9	96	23	48	24, 28	84'4	67'4	17'0	39	25	10	14, 15	88'9	64'5	3'55	...	...	8	12	10	9	W	...	W	Prof. J. G. Cope.
Crawford,	Meadville—																													
	Divinity Hall,[1]	1,200	...	...	...	70'4	93	14	47	4, 24	83'6	57'1	26'5	34	25	18	29	...	...	3'65	...	...	9	3	26	2	S	NW	S	Chas. Graves
Crawford,	Saegertown, A,	1,200	...	...	...	68'3	92	13, 15	41	28	83'2	53'5	29'7	44	28	17	29	...	...	2'13	...	...	10	14	16	1	SW	...	NW	J. G. Apple.
Cumberland,	Carlisle[1] (24 days),	480	...	...	...	73'0	97	13	52	11	87'5	62'2	25'3	35	21, 31	11	14	...	...	1'37	...	...	7	9	11	4	S	S	...	J. E. Pague.
Dauphin,	Harrisburg, A,	361	29'98	30'25	29'69	75'0	93	13, 25	55	28	84'7	65'0	19'7	35	25	7	14	67'0	62'0	1'92	...	...	12	13	10	8	E	E	E	F. Ridgway, Weather Bureau.
Delaware,	Swarthmore, A—																													
	Swarthmore College,	190	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Susan J. Cunningham.
Erie,	Edinboro,*[1]	1,400	...	...	...	69'8	88	25	47	28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. F. Sweet.
Erie,	Erie, A,	681	29'96	30'20	29'76	71'0	90	15	53	4, 10	78'0	63'0	15'0	29	28	8	9	66'0	59'0	1'79	...	...	11	8	16	7	SW	SW	SW	P. Wood, Weather Bureau.
Fayette,	Uniontown,[1]	1,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. Hunt
Franklin,	Chambersburg,[2]	618	...	...	...	74'7	96	13	52	28	86'5	63'2	23'3	33	25	16	27	...	...	2'12	...	...	7	24	5	2	NW	...	NW	G. W. Ludwig
Fulton,	McConnellsburg,[1]	875	...	...	...	72'6	99	25	48	11	88'2	59'1	29'1	45	25	18	23	69'3	61'2	2'90	...	...	10	10	15	0	W	W	W	T. F. Sloan
Huntingdon,	Huntingdon, A—																													
	The Normal College,	650	...	...	...	72'4	99	25	42	28	87'4	57'5	29'9	44	28	14	3	...	...	2'39	...	...	9	23	7	1	W	...	W	Prof. W. J. Swigart.
Indiana,	Indiana—																													
	State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker
Juniata,	Kilmer,[3]	475	...	...	...	76'2	100	25	63	1	...	...	...	...	...	...	...	...	...	2'72	...	...	11	7	24	0	W	...	...	R. J. Mickey.
Lancaster,	Lancaster, A—																													
	Franklin and Marshall College,	411	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	W. E. Busbong.
Lawrence,	New Castle,[1]	932	...	...	...	70'6	96	25	42	11	86'4	54'9	31'5	45	22	13	8	...	...	6'08	...	...	10	10	15	6	S	S	S	Wm. T. Butz.
Lebanon,	Lebanon, A,	458	29'99	30'23	29'68	72'8	95	26	46	28	85'1	60'6	24'5	35	28	5	14	79'0	63'7	2'67	...	...	13	17	11	3	SW	...	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,[1]	520	...	...	...	72'0	92	26	53	28	82'1	63'2	18'9	33	25	9	14	...	...	1'90	...	...	8	19	7	5	SW	SW	NE	Dr. M. H. Boye.
Luzerne,	Drifton (25 days), A,	1,683	29'99	30'20	29'82	67'5	88	26	42	24, 28	80'0	54'0	26'0	41	25	9	14	71'0	58'0	4'66	...	...	8	13	4	8	...	...	...	J. R. Wagner.
Luzerne,	Wilkes-Barre, A,	575	...	...	...	73'0	93	8, 22	45	28	87'5	58'4	29'1	42	25	10	15	...	...	3'00	...	...	7	23	4	4	W	...	W	A. W. Betterly.
McKean,	Smethport, A,	1,500	...	...	...	67'4	90	25	41	11, 24	81'5	53'2	28'3	40	11, 28	10	26, 27	...	...	3'56	...	...	10	10	15	6	SW	...	SW	Armstrong & Brownell.
Montgomery,	Pottstown,	150	...	...	...	76'3	98	26	55	24, 28	87'2	65'4	21'8	37	25	8	14	69'3	62'8	1'90	...	...	8	20	8	3	W	W	W	Charles Moore, D.D.S.
Montgomery,	Skippack, A,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. W. Dambly.
Northampton,	Easton—																													
	Lafayette College,	325	...	...	...	73'0	92	26	50	27	83'6	62'0	21'6	30	31	8	14	...	...	3'51	...	...	7	14	12	5	...	...	...	J. W. Moore
Perry,	(Aqueduct) Logania,*[1]	367	...	...	...	74'6	102	26	47	28	...	...	...	...	...	...	...	...	...	2'30	...	...	11	18	10	3	NW	...	...	Richard Callin
Philadelphia,	U. S. Weather Bureau, A,	117	29'98	30'25	29'68	77'0	94	26	58	24	86'0	67'3	18'7	25	25	11	14	64'0	61'0	2'04	...	...	14	10	12	9	SW	SW	SW	L. M. Dey, Weather Bureau.
Philadelphia,	1529 Centennial Avenue, A,	120	29'98	30'27	29'68	76'6	97	26	57	24	86'3	66'8	19'5	28	25	3	14	67'3	62'1	2'96	...	...	15	14	11	6	N	...	SW	John Comly
Philadelphia,	3911 Locust Street, A,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ralph L. Paddock
Pike,	Blooming Grove,*[1]	...	...	...	...	69'9	93	3	50	24	...	...	...	...	...	...	...	...	...	2'53	...	...	8	...	...	...	...	...	...	John Grathwohl.
Schuylkill,	Girardville[1] (30 days),	1,000	29'92	30'21	29'67	70'2	90	29	48	28	81'2	58'1	23'1	40	29	9	14	...	...	4'87	...	...	7	16	10	4	NW	NW	NW	E. C. Wagner.
Snyder,	Selins Grove, A,	455	29'98	30'26	29'82	75'7	95	26	46	24, 28	69'5	61'8	27'7	45	25	15	29	...	...	2'32	...	...	6	0	25	6	SW	...	SW	J. M. Boyer.
Somerset,	Somerset,[1]	2,250	...	...	...	67'5	93	25	42	8	83'3	50'8	26'5	43	8	14	13	...	...	3'37	...	...	9	15	6	10	SW	SW	SW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	...	...	...	65'1	86	8, 25	36	24	77'4	53'0	24'4	...	...	...	...	...	...	2'50	...	...	10	12	11	8	N	SW	W	H. D. Deming
Union,	Lewisburg, A,	450	29'95	30'16	29'53	72'3	104	17	44	28	85'2	60'3	24'9	44	25	14	15, 22	86'5	67'0	2'35	...	...	9	17	9	5	S	...	S	Prof. W. G. Owens.
Warren,	Columbus,	1,410	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. Loveland
Wayne,	Dyberry,[1]	1,100	...	...	...	65'6	88	8	39	11	80'3	52'2	28'1	45	25	12	15	...	...	4'62	...	...	10	14	11	6	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,[1]	1,000	...	...	...	67'0	87	8	44	20	78'6	55'4	23'2	36	20, 26	10	14	...	...	3'77	...	...	10	...	...	...	...	...	...	John Torrey
Wayne,	(Salem Corners) Hamlinton,[1]	1,600	...	...	...	69'7	91	26	49	24	78'1	61'3	16'8	26	28	4	3	...	...	4'01	...	...	10	16	7	8	NW	...	NW	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,*[1]	1,420	...	...	...	69'6	84	25	58	24	...	...	...	...	...	...	...	...	...	6'36	...	...	11	...	...	...	...	...	...	Murray Forbes
Westmoreland,	Ligonier,	1,750	...	...	...	69'5	94	25	45	11	84'8	54'0	30'8	42	25	20	31	...	...	6'21	...	...	10	18	12	1	...	...	...	J. T. Ambrose.
Wyoming,	South Eaton, A,	660	...	...	...	68'9	89	8, 13	46	11, 28	79'5	58'2	21'3	38	25	8	14	...	...	3'83	...	...	9	17	13	1	S	...	W	B. M. Hall.
York,	York, A,	385	29'95	30'30	29'71	74'5	98	26	48	28	87'1	61'0	25'5	41	25	14	14	75'5	65'7	1'58	...	...	11	18	9	4	NW	...	NW	Mrs. L. H. Grenewald.

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean of 8 + ÷ 2. [3] Mean of 7 + 7 ÷ 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings. † 25 days.

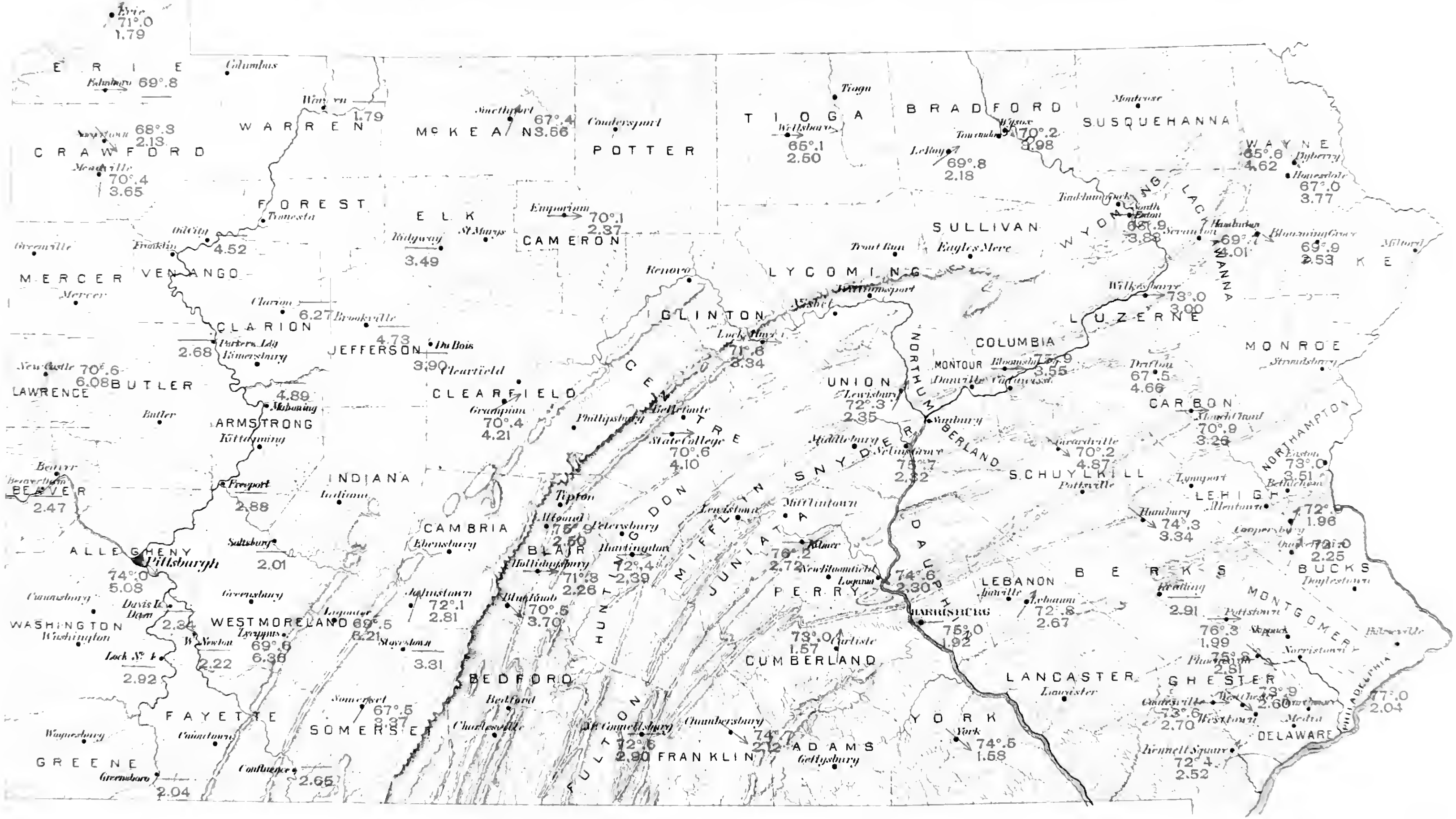
PRECIPITATION DURING JULY, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,			·16					·22				·11	·09		·06							·18				·44			·44			2·53
Brewers Lock,				·17	·00	·21			·06					·07		·20	·54												·16			2·35
Coatesville,		·21	·70		·4		·06	·25					·07	·08		·20	·37	·13								·16			·05			2·70
Coopersburg,			·00	·18		·05		·50					·30	·16		·39													·40			1·96
Doylestown,																																
Dyberry,			·08		·13			·07				·14	·06			·25		·71					·20			1·25			·14			4·62
Easton,			·45			·11		·07								1·52	·04									·02			·17			3·51
Forks of Neshaminy,			·2	*	·1			·12						·2		·10	·15	·12								·02			·47			1·56
Frederick,																																
Hamburg,			·72					·29					·01			1·50		·26											·51			3·34
Honesdale,			·12		1·06			·51					·17		·15	·02		·03				·18				1·24			·26			3·77
Kennett Square,		[illegible]					·05	·18	·04				·30	·16		·04										·55	·11		·22			2·52
Lansdale,																																
Mauch Chunk,			[illegible]			·16		·2						·64		·85											·42		·19			3·26
[illegible]ville,																																
Philadelphia, a.*			·37		·11	·07	·1	·18					·04	·01		·14	·52	·05	·05							·24			·04		·03	2·04
Philadelphia, b.			·13		·50	·10		·5	·01				·05	·02		·25	·59	·27	·01							·22			·01	·07	·04	2·96
Philadelphia, c.																																
Phœnixville,			·31		·70	·22	·1	·15					·03	·02		·13	·54						·01			·12			·34	·02		2·81
Point Pleasant,																																
Pottstown,			·14		·13		·07	·24					·10			·42										·15			·24			1·09
Quakertown,			·21		·42			·41					·19	·07		·37	·04						·03						·31			2·25
Reading,			·57		·4	·0							·30	·12		1·00							·01						·10			2·91
Salem Corners,			·4						·30				·20	·75		·40		·05					·08				·58		·55			4·01
Seisholtzville,																																
Smith's Corner,																																
Swarthmore,																																
West Chester,		·35	·23		·03		·05	·10					·02	·13		·12		·65								·32			·07	·03		2·60
Westtown,																																
Susquehanna Basin.																																
Altoona,			·5				·50		·13					·59		·15	·78										·04		·16			2·50
Aqueduct,			·24		·04	·05	·1	·12					·22		·93		·10						·31						·16		·02	2·30
Bloomsburg,					·16	·02		·15					·32			·66							·05			1·20			·59			3·55
Blue Knob,			·4		·4		·15	·12					·62	·40	·03			·50								·4			·51		·03	1·70
Carlisle,						·02	·14	·32						·14		·13						*	*	*	*	*	*	*	·07		·15	1·57
Drifton,	*		1·00	*	·25				*	·18			·05	·74	·45	*							*			·80			·74	*		4·66
Emporium,			·11		·03	·04		·2					·06		·35		·22						·53			·50			·24			2·37
Girardville,			·92		·15			1·15					·87		1·14								·18						·46	*		4·87
Grampian,			·28			·11	·27	·24					·22			·40	1·60	·22				·11				·04			·65			4·21
Harrisburg,†					·01	·14	·41	·51	·01				·12	·04	·01	·46										·02			·10		·09	1·92
Hollidaysburg,							·44						·57		·26		·56	·04								·07			·32			2·26
Huntingdon,						·31	·35	·07					·29		·06	·17	·79						·22						·13			2·30
Kilmer,			·03		·24	·05	·11	·10					·36		·75		·25						·16			·04			·11			2·72
Lancaster,																																
Lebanon,		·01	·59		·56	·21	·18	·13					·09	·25		·60							·07			·02			·08		·08	2·67
Le Roy,			·10		·02			·25					·05	·25	·52	·05	·02	·33					·02			·37			·20			2·18
Lewisburg,						·01		·54					·85			·58	·04						·06			·20	·04		·03			2·35
Lock Haven,			·02			·01	·0	·47					·15	·10	1·20		·45						·07			·02			·76			3·14
Selins Grove,							·03	·53					·35			·79							·25						·37			2·32
South Eaton,			·46					·77					·61	·08		·37		·80					·03			·36			·35			3·83
State College,					·41	·14	·14	·7					·42		·81	·03	·58						·11			·41			·45			4·10
Wellsboro,																																2·50
Wilkes-Barre,			·37					·27					·27		·57			·55					·11			·26			·60			3·00
Wysox,			·7		·49			·46					·67		·10			·18				·57				·40		·35				3·98
York,		·09	·12			·11	·30	·07					·27	·09		·04										·26			·17		·06	1·58

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,			·11						·72					·18		·42	·12										[illegible]		[illegible]			[illegible]
Brookville,			·11			·03	·33		·97					·58		·41	·56	1·12					·56				[illegible]		[illegible]			[illegible]
Clarion,			·30				·50		·53					·70		1·33	·38	1·22					·27				[illegible]		[illegible]			[illegible]
Columbus,																																
Confluence,		·11		·02			·04	·27	·70					·54	·15		·01	·16									[illegible]					[illegible]
Davis Island Dam,			·25				·02		·14					·41		·57	·03	·05									[illegible]		[illegible]			[illegible]
DuBois,			·05			·69	·34		·36					[illegible]		·26	·66	·11					·13			[illegible]			[illegible]			[illegible]
Freeport,			·16						·18					·77	·02	·21	·05	·44									[illegible]		[illegible]			[illegible]
Greensboro,		·15		·10					·15								·25										[illegible]					[illegible]
Immel Reservoir,	·11		·20				2·15	·97					·72		·25	·08	·25	·13								·74			[illegible]			[illegible]
Indiana,																																
Johnstown,			·20			·14	·14	·02	·01				·57	·16	[illegible]	[illegible]	·42	*								·35	[illegible]		[illegible]			[illegible]
Ligonier,		·30				·95	1·11						·72		·60		·46	[illegible]								[illegible]			[illegible]			[illegible]
Lock No. 4,		·02	·02						·25					·15		·18	·17	·04									[illegible]		[illegible]			[illegible]
Mahoning,			·58				·32		·12					1·26	·55	·52	·45	·35									[illegible]		[illegible]			[illegible]
Meadville,			·25			·23		·61							·30	·37	1·50	·07					·27						[illegible]			
New Castle,			·27			·08		·06					1·4	·98		·50	·50									·52			[illegible]		[illegible]	[illegible]
Oil City,			·41			·26	·32		·30					·50	·04	·40	·35	1·08					·18				·15		[illegible]			[illegible]
Parker's Landing,			·14				·32		·22					·73		·35	·41	·05					·22				·22		[illegible]			[illegible]
Pittsburg,†			·25				·10	·13			·11		·46		·71	·58	·51	·10								[illegible]			[illegible]			
Ridgway,			·17			·27		·48					[illegible]		·29		·48					[illegible]										[illegible]
Saegertown,			·07			·15		·13					·01		·45	·54	·47						[illegible]						[illegible]			[illegible]
Saltsburg,			·8	·10	*	·03								·68		·72	[illegible]										[illegible]		[illegible]			[illegible]
Smethport,			·40		·15			·33					·20		·63	·10	·25						[illegible]			[illegible]			[illegible]			[illegible]
Somerset,	·10		·33				·85	·20					[illegible]		·15											[illegible]			[illegible]		[illegible]	
Stoyestown,							·92	·98	·15				·30	·27	·05												[illegible]		[illegible]			
Uniontown,																																
Warren,			·10				·08		·52					·01		·58	·20	·07					·15									
West Newton,		·02	·15				·15	·05	·12					·72		·06	·28	·13									[illegible]		[illegible]			
Potomac Basin.																																
Chambersburg,	·47					·60		·25					·05														[illegible]		[illegible]			[illegible]
McConnellsburg,						·01	·20	·55					·19	·20	·51		·24									·41			[illegible]			[illegible]
Lake Basin.																																
Erie,†			·20			·05		·42					·06	·01		·09	·02	·04				·13	·58						[illegible]			[illegible]

† U. S. Weather Bureau Stations. * Missing.

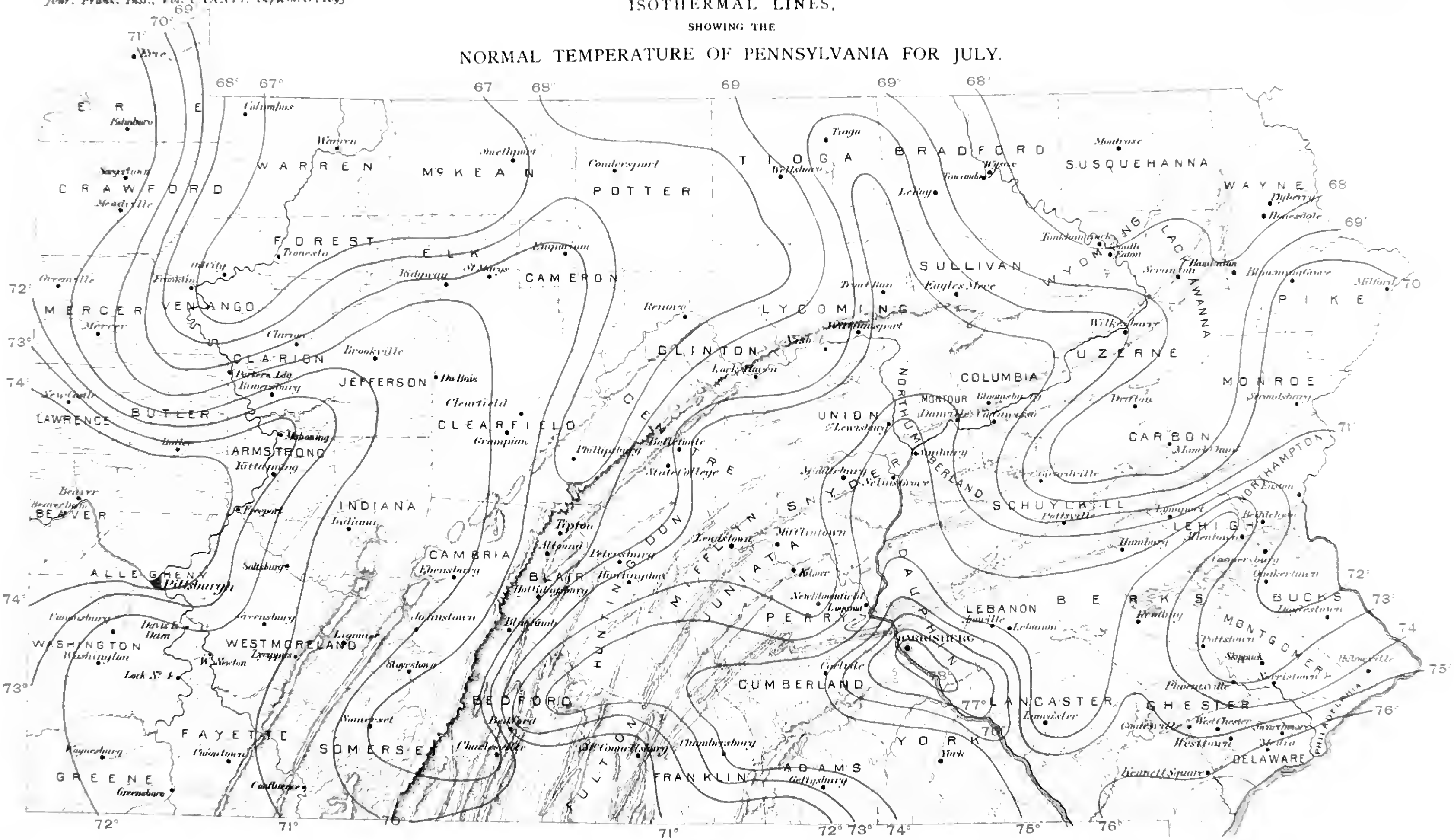
MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR JULY. 1893



ISOTHERMAL LINES,

SHOWING THE

NORMAL TEMPERATURE OF PENNSYLVANIA FOR JULY.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

H. L. BALL, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR AUGUST, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, August 31, 1893.

GENERAL REVIEW.

The most notable features of the month's weather were the drouth of the first two decades and the hurricanes on the 23d and 28th.

Of the temperature, no more need be said than that it was normal, considering the State as a whole, and that neither extremes of heat nor cold occurred. The greater part of the month gave fair and pleasant weather.

The rainfall during the first two decades was very light, and that which fell was badly distributed. Drouth, in its most serious form, existed. In the sections, of which Tioga in the north and Bedford in the south were the centres, no appreciable rainfall was received. In those sections it is said that during more than two months the ground had not been thoroughly wet. Over the whole State, rivers, springs and wells were low and the ground parched and hard. Crops of all kinds suffered severely and their yield materially shortened. Heavy local showers on the 6th brought relief, as well as destruction, to portions of Chester, Lancaster and York Counties. On that date a terrible hail-storm passed over a part of York County, destroying all crops in its path. [A full account of this storm will be found in the notes of the York observer, printed elsewhere.] The long prevailing drouth was partially relieved in Eastern Pennsylvania by heavy showers on the 19th and 20th, and the heavy rains on the night of the 23d. The hurricane of

the 23d was of great severity but was confined almost entirely to the southeastern counties. While Bucks, Lehigh and neighboring counties received from five to eight inches of rainfall from the rains of the 19th, 20th and 23d, the counties west of the mountains had less than one-fourth of an inch. The path of the second hurricane, that of the 28th, lay through the central portion of the State, and the accompanying rains terminated the drouth in all sections.

The high winds accompanying and following both of these hurricanes completely prostrated most of the standing crops and blew off great quantities of fruit.

Though the average rainfall was slightly above the normal, the distribution was very uneven. The counties along the Delaware and Lehigh, especially Bucks County, received far more rain than elsewhere, the excess over the normal at some stations being nearly four inches. From Philadelphia westward, and including all the southern and southwestern counties, the rainfall was below the normal. In the other sections about the usual amount was received.

At Philadelphia the total deficiency in rainfall for the month was 2·41, at York 0·64, Harrisburg 1·16, Pittsburgh 0·46, and at Erie an *excess* of 0·28 inch.

From January 1, 1893, to August 31, 1893, the deficiency in temperature was, at Philadelphia 260°, York 399°, Pittsburgh 378°, and at Erie 367°.

For the same period the deficiency in precipitation was, at Philadelphia 3·32, York 4·60, Harrisburg 7·01 inches, and at Pittsburgh and Erie an *excess* of 1·76 and 3·97 inches, respectively.

EXCESSIVE PRECIPITATION.

[*One inch in one hour, or two and one-half inches in twenty-four hours.*]

Stations.	Amount. (Inches and Hundredths.)	Time. h.	Time. m.	Date.
Blooming Grove,	3·11	16	30	23d 11 p. m. to 24th 3.30 p. m.
Blue Knob,	3·15	24	—	29th
Carlisle,	2·90	24	—	29th
Doylestown,	2·98	24	—	20th
Doylestown,	3·28	24	—	24th
Forks of Neshaminy,	3·26	24	—	24th
Hamburg,	3·40	24	—	19th
Kilmer,	4·00	21	15	28th 7.30 a. m. to 4.45 a. m. 29th.
Meadville,	3·04	24	—	28th to 29th.
Ottsville,	3·12	24	—	20th
Point Pleasant,	3·36	24	—	20th
Point Pleasant,	2·71	24	—	24th
Pottstown,	1·35	1	15	20th
Quakertown,	4·75	5	50	19th 7 p. m. to 11 p. m. 2·95 in. 20th 8.10 a. m. to 11 a. m. 1·80 in.
Quakertown,	2·58	7	—	23d 8.50 p. m. to "early a. m." 24th.
Seisholtzville,	2·79	24	—	20th
Skippack,	2·67	24	—	19th to 20th.
Smethport,	2·50	23	30	28th 9 p. m. to 29th 8.30 a. m.
Smith's Corner,	3·23	24	—	20th
Uniontown,	2·63	24	—	28th to 29th.

	Mean Temperature.	Mean Precipitation. Inches.
August 1888,	$69^{\circ}.5$	7·05
1889,	$67^{\circ}.4$	3·24
1890,	$68^{\circ}.4$	5·76
1891,	$69^{\circ}.7$	5·09
1892,	$71^{\circ}.3$	3·77
1893,	$70^{\circ}.2$	4·50

TEMPERATURE.

The mean temperature for August, 1893, was $70^{\circ}.2$, which is just the normal, and $1^{\circ}.1$ below the corresponding month of 1892.

The mean of the daily maximum and minimum temperatures, $82^{\circ}.7$ and $58^{\circ}.1$, gives a monthly mean of $70^{\circ}.4$, with an average daily range of $24^{\circ}.6$.

Highest monthly mean, $76^{\circ}.0$ at Philadelphia. [Weather Bureau.]

Lowest monthly mean, $63^{\circ}.2$ at Wellsboro.

Highest temperature recorded during the month, 99° on the 11th at Lock Haven, and on the 18th and 25th at Huntingdon.

Lowest temperature, 30° on the 14th at State College.

Greatest local monthly range, 62° at State College.

Least local monthly range, 35° at Philadelphia. [Weather Bureau.]

Greatest daily range, 50° at Saegertown on the 3d, Ligonier 15th, Huntingdon 16th, and State College on the 26th.

Least daily range, 2° at Salem Corners [Hamlinton] on the 24th.

BAROMETER.

The mean pressure for the month, 29·99, is about ·01 inch above the normal. At the United States Weather Bureau Stations, the highest observed was 30·25 at Erie on the 31st, and the lowest 29·38 at Harrisburg on the 29th.

PRECIPITATION.

The average rainfall, 4·50 inches for the month, is an excess of over one-fourth of an inch.

The largest monthly totals in inches were Doylestown, 9·99; Point Pleasant, 9·71; Quakertown, 8·90, and Smith's Corner, 8·63 inches.

The least were Immel Reservoir (Lycippus), 1·68; Ligonier, 2·19; Lock No. 4, 2·42; and Philadelphia [Weather Bureau], 2·43 inches.

WIND AND WEATHER.

The prevailing direction of wind was from the Northwest.

Average number: rainy days, 8; clear days, 14; fair days, 10; cloudy days, 7.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 6th, 11th, 19th, 27th; Hollidaysburg, 6th, 11th; Wysox, 27; Le Roy, 25th, 27th; Quakertown, 19th; State College, 19th, 26th; Coatesville, 6th, 17th, 20th; Kennett Square, 6th, 17th, 20th;

Grampian, 29th; Lock Haven, 6th, 12th, 19th, 24th, 27th, 28th; Meadville, 4th, 5th, 11th, 16th, 18th; Carlisle, 6th, 12th, 19th, 29th; Harrisburg, 6th, 12th, 19th; Huntington, 19th; Kilmer, 6th, 19th, 20th; Lancaster, 6th, 17th, 24th; Lebanon, 6th, 19th; Coopersburg, 17th, 19th, 20th; Drifton, 7th, 18th, 19th, 21st 24th, 29th; Wilkes-Barre, 12th, 17th, 19th, 24th, 29th; Smethport, 1st, 6th, 18th; Pottstown, 6th, 19th, 20th; Skippack, 5th, 20th; Easton, 6th, 12th, 17th, 19th; Aqueduct, 26th; *Philadelphia*, 6th, 12th, 17th, 20th; Centennial Avenue, 6th, 12th, 17th, 20th; Blooming Grove, 6th, 19th; Girardville, 19th; Selins Grove, 6th, 12th, 24th; Somerset, 23d, 26th; Dyberry, 6th, 17th, 19th, 20th; Salem Corners, 5th, 6th, 19th; South Eaton, 6th, 19th, 20th, 27th; York, 12th; Chambersburg, 6th, 28th; Wellsboro, 8th, 19th, 27th; Phœnixville, 6th; Johnstown, 6th, 26th; Emporium, 6th, 18th, 19th, 25th, 27th.

Hail.—Quakertown, 19th; Carlisle, 6th; Lancaster, 17th; York, 6th; Chambersburg, 6th.

Frost.—Blue Knob, 30th; Smethport, 14th; Blooming Grove, 15th; Somerset, 15th; Dyberry, 14th; Wellsboro, 14th, 15th, 16th, 31st.

Coronæ.—Blue Knob, 24th; Wilkes-Barre, 7th; Dyberry, 4th.

Aurora.—Le Roy, 6th, 12th; Quakertown, 6th; Aqueduct, 6th, 8th; Selins Grove, 6th, 31st.

Solar Halo.—Le Roy, 31st; Philadelphia, 14th; Centennial Avenue, 3d, 11th, 14th; Dyberry, 4th.

Lunar Rainbow.—Wilkes-Barre, 27th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for August, 1893.

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level. Mean.	Barometer Highest.	Barometer Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
Allegheny,	Pittsburgh, A.	820	30·00	30·22	29·57	71·0	92	9, 25	50	30	82·5	60·4	22·1	33	9, 15	9	6, 28	65·1	57·8	2·94	...	...	7	15	12	4	NE	...	N	O. D. Stewart, Weather Bureau.
Berks,	Hamburg,	380	...	...	...	73·5	98	9, 11	49	31	86·8	60·2	26·6	40	16	10	29	...	...	5·74	...	...	5	16	7	4	NW	SE	NW	William Shipe
Berks,	Reading, A	280	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·25	...	...	...	...	...	...	...	...	...	Franklin Yager
Blair,	Altoona, B,	1,181	...	...	...	73·1	93	12	51	15	83·4	63·2	20·2	27	10	12	1	...	...	2·92	...	...	8	...	...	...	...	...	...	Dr. C. B. Dudley
Blair,	Blue Knob, A,	2,500	...	...	...	68·6	85	11	51	7	76·9	60·4	16·5	26	9	8	29	...	...	3·58	...	...	4	9	13	4	NW	NW	NW	A. H. Boyle
Blair,	Hollidaysburg (21 days),	947	...	...	...	70·6	98	11	39	14	85·7	51·5	34·2	48	9	21	12	...	...	4·18	...	...	[illegible]	12	[illegible]	4	NW	W	NW	Prof. J. A. Stewart
Bradford,	Wysox[1],	718	30·01	30·25	29·31	68·1	95	11	38	14	81·2	53·9	27·3	41	10	10	29	79·8	61·5	5·43	...	...	14	14	3	14	NW	NW	NW	Charles Beecher
Bradford,	Le Roy,	1,400	...	...	...	68·3	96	11	47	14	78·2	58·5	19·7	30	11	8	29	...	...	5·92	...	...	13	12	14	5	SW	SW	SW	G. W. T. Warburton
Bucks,	Forks of Neshaminy[1] (29 days),	304	...	...	...	72·9	...	...	...	...	...	...	...	...	...	...	...	...	...	6·93	...	...	10	15	9	5	N	N	W	J. C. Hilsman
Bucks,	Quakertown,[1]	536	30·00	30·46	29·61	70·8	98	12	48	31	86·0	58·7	27·3	43	11	11	20	75·5	62·3	8·90	...	...	9	11	16	4	NE	NW	NE	J. L. Heacock
Cambria,	Johnstown, A,	1,184	...	...	...	70·4	96	10	41	15	85·6	55·3	30·3	48	15	12	28	...	...	2·20	...	...	9	15	10	6	S	...	S	E. C. Lorentz
Cameron,	Emporium, A,	1,050	30·03	30·35	29·37	67·4	91	11	41	15	81·3	54·1	27·2	43	15, 16	12	29	88·0	59·5	3·00	...	...	9	10	15	6	NW	...	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	...	...	...	70·4	95	9	46	31	83·2	57·5	25·7	42	9	8	29	...	...	4·45	...	...	4	14	12	5	W	W	W	F. C. Wintermute
Centre,	State College[1]—Agricultural Experiment Station,	1,191	...	...	...	68·5	92	11	30	14	80·8	46·9	33·9	50	26	18	1	70·8	58·0	3·14	...	...	7	12	14	5	W	W	W	Prof. Wm. Frear.
Chester,	West Chester,[1]	455	29·97	30·20	29·40	72·5	91	25	54	14	82·7	64·1	18·6	30	6	8	28	68·0	61·0	3·05	...	...	9	22	3	6	N	NW	SE	J. C. Green, D. D. S.
Chester,	Coatesville,[1]	380	...	...	...	72·0	94	25	48	14	85·4	60·3	25·1	38	16	12	28	...	...	4·68	...	...	8	19	3	4	W	W	W	W. T. Gordon.
Chester	Kennett Square, A,[2]	275	...	...	...	70·3	80	25	60	31	...	...	...	...	...	...	...	...	...	3·74	...	...	9	14	13	4	N	...	NW	B. P. Kirk.
Chester	Phœnixville, A,	190	[illegible]	30·25	29·44	74·6	94	12	52	31	84·9	64·2	20·7	34	16	7	14	69·3	62·2	3·61	...	...	8	13	9	9	NW	...	NW	Knowles Croskey
Chester,	Westtown,	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Harry Alger.
Clearfield,	Grampian *[1]	1,450	...	...	...	67·6	92	11	48	30	79·7	58·2	21·5	38	16	10	29	...	...	3·26	...	...	8	10	15	6	SW	W	SW	Nathan Moore
Clinton,	Lock Haven,[1]	560	...	...	...	69·7	99	11	42	14, 15	87·0	54·9	32·1	49	15	12	29	...	...	2·32	...	...	7	19	7	5	W	W	W	Prof. J. A. Robb
Columbia,	Bloomsburg, A—State Normal School,	500	...	...	...	71·8	97	21	49	31	81·2	60·3	22·9	37	16	11	24, 29	...	...	3·07	...	...	6	10	9	12	E	...	E	Prof. J. G. Cope.
Crawford,	Meadville—Divinity Hall,[1]	1,200	...	...	...	66·0	89	11	43	3, 31	77·4	51·6	25·8	40	3	14	12	...	...	7·03	...	...	9	6	19	6	N	S	W	Chas. Graves
Crawford,	Saegertown, A,	1,200	...	...	...	66·1	94	10, 11	38	3	81·6	50·7	30·9	50	3	10	17	...	...	5·20	...	...	11	16	11	4	NW	...	NW	J. G. Apple
Cumberland,	Carlisle,[1]	480	...	...	...	70·8	95	11, 25	48	15	85·7	59·8	25·9	40	15	6	28	...	...	5·82	...	...	7	11	12	8	W	SW	W	J. E. Pague
Dauphin,	Harrisburg, A,	361	29·98	30·22	29·38	73·0	95	5	54	14	83·0	63·0	20·0	41	5	7	28	68·0	60·0	3·69	...	...	9	13	8	10	E	E	E	F. R. [illegible], Weather Bureau
Delaware,	Swarthmore, A—Swarthmore College,	190	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Susan J. Cunningham
Erie,	Edinboro,*	1,400	...	...	...	66·6	86	10, 11	44	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. F. Sweet
Erie,	Erie, A,	681	29·99	30·25	29·67	68·0	88	10	50	30	76·0	61·0	15·0	21	13	5	29	65·0	56·0	3·01	...	...	8	8	15	5	NE	...	NE	P. W[illegible], Weather Bureau.
Fayette,	Uniontown,[1]	1,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. Hunt
Franklin,	Chambersburg,[2]	618	...	...	...	73·2	95	26	49	15	84·4	62·1	22·3	34	16	10	29	...	...	2·61	...	...	3	21	5	5	NW	NW	NW	G. W. Ludwig
Fulton,	McConnellsburg,[1]	875	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T. F. Sloan
Huntingdon,	Huntingdon, A—The Normal College,	650	...	...	...	70·3	99	18, 25	43	15	86·9	53·8	33·1	50	16	13	29	...	...	3·49	...	...	4	24	2	5	W	...	W	Prof. W. J. Swigart
Indiana,	Indiana—State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker
Juniata,	Kilmer,[2]	475	...	...	...	74·9	97	11, 27	60	15, 31	...	...	...	...	...	...	...	...	...	5·19	...	...	6	9	18	4	W	W	W	R. J. M[illegible]key
Lancaster,	Lancaster, A (24 days)—Franklin and Marshall College,	411	30·02	30·28	29·77	73·7	96	1	50	1	86·2	61·2	25·0	37	9	10	28	68·5	60·9	3·77	...	...	5	11	9	4	W	...	W	W. E. Bushong
Lawrence,	New Castle,[1]	932	...	...	...	66·8	92	25	39	31	83·3	50·4	32·9	45	7	14	29	...	...	3·37	...	...	7	17	10	4	SW	SW	SE	Wm. T. Butz
Lebanon,	Lebanon, A,	458	29·97	30·20	29·39	71·4	96	9	48	31	...	...	...	...	...	...	...	76·3	62·4	5·30	...	...	7	16	10	5	NE	...	NW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,[1]	520	...	...	...	71·5	99	9, 11	53	31	81·0	62·8	18·2	29	16	7	29	...	...	6·22	...	...	8	17	9	5	NE	NW	NE	Dr. M. H. Boye
Luzerne,	Drifton (27 days), A,	1,683	29·98	30·16	29·81	67·4	92	11	42	31	79·8	55·1	24·7	45	11	9	10, 29	72·0	59·0	6·65	...	...	[illegible]	14	5	5	...	...	...	J. R. Wagner
Luzerne,	Wilkes-Barre, A,	575	...	...	...	71·3	97	10, 11	44	14	85·2	57·5	27·7	44	16, 17	3	30	...	...	3·76	...	...	5	21	7	3	W	...	W	A. W. Betterly
McKean,	Smethport, A (30 days),	1,500	...	...	...	65·1	91	11	37	14	79·3	51·0	28·3	44	15	9	29	...	...	4·15	...	...	9	10	15	5	SW	...	SW	Armstrong & Browne
Montgomery,	Pottstown,	150	...	...	...	74·8	95	12	52	14	86·0	63·7	22·3	34	11, 16	10	28	71·0	63·0	4·52	...	...	6	22	5	4	W	W	W	Charles Moore, D. D. S.
Montgomery,	Skippack, A,	...	...	...	...	72·8	93	12	47	14	84·8	60·8	24·0	41	14	6	20	...	...	5·76	...	...	8	10	2	10	W	...	W	B. W. Dambly.
Northampton,	Easton[1]—Lafayette College,	325	...	...	...	72·5	93	12	50	30	82·0	63·0	19·0	28	7	4	2	...	...	5·29	...	...	6	15	10	6	...	...	...	J. W. Moore
Perry,	Aqueduct Logania,*	367	...	...	...	73·2	97	27	47	15	...	...	...	...	...	...	...	...	...	3·78	...	...	11	15	9	7	N	N	N	Richard Ca[illegible]
Philadelphia,	U. S. Weather Bureau, A,	117	29·98	30·22	29·47	76·0	93	9	58	14	84·8	66·5	18·3	29	6	13	28	68·0	61·0	2·43	...	...	9	10	12	9	N	N	N	L. M. Dey, Weather Bureau
Philadelphia,	1523 Centennial Avenue, A,	120	29·98	30·22	29·47	75·2	93	25	56	14	84·4	66·1	18·3	25	6	9	28	70·9	62·0	3·90	...	...	10	13	12	6	N	...	SW	John Comly
Philadelphia,	3911 Locust Street, A,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ralph L. Pad[illegible]
Pike,	Blooming Grove,*[1]	...	...	...	...	67·2	94	9, 10	52	14	...	...	...	...	...	...	...	...	...	5·35	...	...	6	...	...	...	...	...	...	John Grat[illegible]
Schuylkill,	Girardville,[1]	1,000	29·94	30·19	29·68	69·2	90	9, 10	49	14, 31	80·5	53·6	[illegible]	36	16	9	28	...	...	4·11	...	...	8	16	10	5	NW	NW	W	E. C. Wagner
Snyder,	Selins Grove, A,	455	30·04	30·34	29·71	73·8	97	9	42	15	87·7	59·9	27·8	41	15	14	31	...	...	4·07	...	...	7	[illegible]	21	[illegible]	SW	...	SW	J. M. Boyer
Somerset,	Somerset,[1]	2,250	...	...	...	70·2	96	25, 28	42	8, 21	84·3	50·1	[illegible]	41	15	13	29	...	...	3·93	...	...	6	13	12	6	NW	NW	NW	W. M. Schrock
Tioga,	Wellsboro,*	1,327	...	...	...	63·2	90	11	34	14	...	...	...	...	...	...	...	...	...	4·50	...	...	10	13	8	10	N	N	N	H. D. Deming
Union,	Lewisburg, A,	450	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. W. G. Owens
Warren,	Columbus,	1,410	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. Love and
Wayne,	Dyberry,[1]	1,100	...	...	...	66·1	93	10, 11	35	14	80·9	52·1	28·8	44	16	8	24	...	...	4·45	...	...	5	...	...	...	NW	W	NW	Theodore Day.
Wayne,	Honesdale,[1]	1,000	...	...	...	66·5	87	27	42	14	77·6	55·5	22·1	34	14	6	24	...	...	3·17	...	...	9	...	...	...	...	...	...	John Torrey
Wayne,	(Salem Corners) Hamlinton,[1]	1,600	...	...	...	66·9	92	10	47	14	78·6	58·4	20·2	35	9	2	24	...	...	5·12	...	...	10	11	9	11	NW	W	NW	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,*	1,420	...	...	...	68·1	...	...	...	...	...	...	...	...	...	...	...	...	...	1·08	...	...	4	...	...	...	...	...	...	Murray Forbes
Westmoreland,	Ligonier (30 days),	1,750	...	...	...	67·9	95	27	37	15	84·7	51·7	31·0	50	15	7	29	...	...	2·19	...	...	5	23	4	3	...	...	...	J. T. Ambrose
Wyoming,	South Eaton, A,	660	...	...	...	68·0	90	10, 11	45	15	78·7	57·2	21·5	45	16	8	24	...	...	5·41	...	...	9	19	4	8	SW	...	SW	R. M. Hall
York,	York, A,	385	29·95	30·17	29·76	72·1	95	25	47	14	84·7	59·3	25·4	38	16	11	29	80·8	64·8	3·40	...	...	6	18	7	6	NW	...	NW	Mrs. L. H. Grenewald.
	July, 1893. *Report received too late for July Bulletin.*																													
	Lancaster (18 days),	...	29·97	30·21	29·80	73·3	91	9, 18	53	10, 11	84·5	62·2	22·3	34	10	11	1	76·4	65·4	1·23	...	...	6	7	9	2	SE	...	SW	

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean of 8 + 8 + 2. [3] Mean of 7 + 7 + 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings. † 25 days.

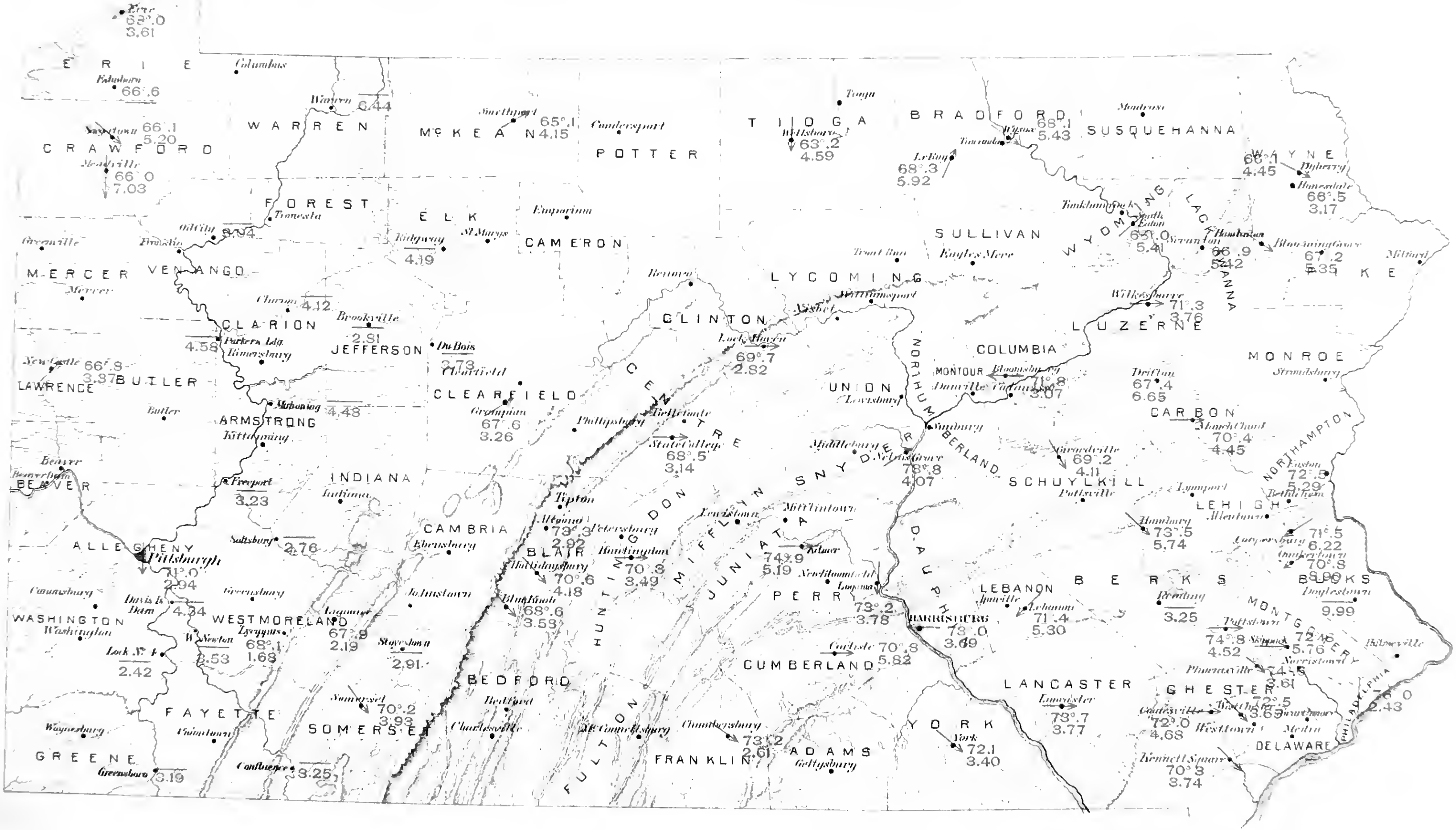
PRECIPITATION DURING AUGUST, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,					'12												'28			'44				3'11	'07				1'33			5'35
Brewers Lock,	'06				'12	'43											'05			'90				1'62					'69			3'96
Coatesville,				'04		'93						'08					'20			1'12			'03	1'24					1'04			4'68
Coopersburg,					'01	'01						'03					'36		'72	2'26			'03	1'90					'90			6'22
Doylestown,					'24	'02						'90					'64			2'98				3'28					2'13			9'99
Dyberry,																	'69		'08				'40	1'88					1'40			4'45
Easton,						'02						'01					'14			2'08				2'11					'73			5'29
Forks of Neshaminy,	'14				'19	'06						'05				'08	'33			1'38			'08	3'26					1'36			6'93
Frederick,	'09					'06											'05			1'81				1'71					'74			4'46
Hamburg,												'33					'08		3'40					1'13					'80			5'74
Honesdale,						'03						'03					'40		'12	'01			'08	1'72	'05				'73			3'17
Kennett Square,	'02				'08	'50						'21					'25	'02		'80				1'35					'51			3'74
Lansdale,				'12								'03				'07	'08		1'90					2'12					1'00			5'32
Mauch Chunk,																	'11			1'22				1'31					1'61			4'45
Ottsville,	'51				'50							'11	'01				'10			3'12				2'10					1'05			7'46
Philadelphia, a†	'15				'12	'07						'02					[illegible]			'08			'05	1'32					'55			2'43
Philadelphia, b.	'08				'13	'30						'10					'06	'01		'07			'06	2'20					'74			3'90
Philadelphia, c,																																
Phœnixville,					'06	'12	'01					'01					'07			1'12				1'59					'57			3'61
Point Pleasant,	'47				'07							'21					'40		'07	3'36				2'71					2'42			9'71
Pottstown,						'04											'06		1'04	1'35				1'28					'75			4'52
Quakertown,	'05				'07							'23					'46		4'95	1'80			'01	2'58					'75			8'90
Reading,				'01	'01	'01						'01					'10		'03	1'26				1'18					'64			3'25
Salem Corners,					'01	'02							'4				'40			'55	'02			2'00	'22	'10			2'06			5'42
Seisholtzville,												'12					'36		'04	2'79				4'07					1'04			6'44
Skippack,	'10				'05	'02											'07		'85	1'74				2'00					'92			5'76
Smith's Corner,	'41	'05										'08					'41			3'23				2'45					2'00			8'63
Swarthmore,																																
West Chester,	'02				'05	'77						'02					'08			'84			'12	1'16					'56			3'63
Westtown,																																
Susquehanna Basin.																																
Altoona,						'03						'03	'07							'03				'23			'08		2'40	'05		2'92
Aqueduct,						'04						'10					'08	'01	'25	'54			'15	'65		'03		'55	1'40			3'78
Bloomsburg,												'44						'02	'08	'22				1'37					'94			3'07
Blue Knob,						'04																		'26			'13		3'15			3'58
Carlisle,						'64						'01	'10							1'47			'20	'50					2'90			5'82
Drifton,						*	'14						*				'09	'80	1'01	*	'89			1'71			*		1'01			6'65
Emporium,						'06						'02					'30		'17					'34	'06		'30	'12	1'36			3'00
Girardville,						'06						'02					'04		'72					'54	'86			'60	1'27			4'11
Grampian,						'34					'18						'15							'25	'03		'23	'17	1'68			3'26
Harrisburg,†						'35						'13	'01				'05		'40	'93			'06	'54					1'22			3'69
Hollidaysburg,												'21			*	*	*	*	*	*	*	*	*	*	'52	'05		1'00	2'40			4'18
Huntingdon,						'06						'40							'40										2'63			3'49
Kilmer,						'02					'05						'14		'10	'16				'72				1'20	2'80			5'19
Lancaster,				'01		'57				*	*	*	*	*	*	*	'24							1'72					1'23			3'77
Lebanon,						'02						'08					'05		1'33	1'07				1'70					'99			5'30
Le Roy	'02					'17						'46					'50	'15	'05	'06	'23			1'08	'30		'85	'05	2'00			5'92
Lewisburg,																																
Lock Haven,						'33						'23					'12		'06					'63			'19		1'26			2'82
Selins Grove,						'09						'55							'10	'09				'59			'45		2'20			4'07
South Eaton,						'07						'45					'34		'18	1'43	'15			1'86			'24		'69			5'41
State College,						'24					'27	'22					'07		'09					'21		'21	'08	'15	1'60			3'14
Wellsboro,						'04					'05	'35					'26	'10	'24	'05				1'25			'40		1'85			4'59
Wilkes-Barre,												'25					'58		'22					1'69					1'02			3'76
Wysox,					'07	'02						'61				'15	'03	'07	'06	'24			'83	'81	'20		'59	1'70	'05			5'43
York,						1'03						'50					'07			'14				'65					1'01			3'40

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,	'31			'35	'02	'16						'13	'04				'17		'25								[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Brookville,						'47						'28	'08				'09		'03				[illegible]			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Clarion,						'65						'13	'03				'24		'06							[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Columbus,																																
Confluence,	1'18			'02									'12				'16							'14		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Davis Island Dam,	'86			'25	'68	'05							'09				'14		'10								[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
DuBois,						'65											'03	'08	'18					'32	'16	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Freeport,	'02			'05		'24											'07		'09							'09		[illegible]	[illegible]	[illegible]		[illegible]
Greensboro,	'92				'01							'11	'08				'52												[illegible]	[illegible]		[illegible]
Immel Reservoir,												'18				'23	'13												[illegible]			[illegible]
Indiana,																																
Johnstown,						'06						'02				'01	'04							'25		[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Ligonier,					*							'08					'13	'17										[illegible]	[illegible]			[illegible]
Lock No. 4,				'17	'03								'09				'15												[illegible]	[illegible]		[illegible]
Mahoning,	'03					'35						'35	'03				'19		40							[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Meadville,				'45		'60					1'44	'39				'14	'22	'55										[illegible]	[illegible]			[illegible]
New Castle,						'24						'35				'30		'15	25								[illegible]		[illegible]			[illegible]
Oil City,						'25						'21	15						03								[illegible]		[illegible]			[illegible]
Parker's Landing,						'28	'01					'06	'04				'13		10							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Pittsburg,†				'26								'25				'01	'13	06											[illegible]			[illegible]
Ridgway,					'92											'20		'17					[illegible]	20		[illegible]	[illegible]	[illegible]				[illegible]
Saegertown,					'06	'14					'69	'97				'07	'06	'14	11								[illegible]	[illegible]	[illegible]			[illegible]
Saltsburg,	'40					'29							22				'14												[illegible]			[illegible]
Smethport,	'20			*		'30						'15					'40		20					'30			[illegible]	[illegible]	[illegible]			[illegible]
Somerset,												'40									'15		[illegible]			[illegible]		[illegible]	[illegible]			
Stoyestown,	'31														'39				'14						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Uniontown,																																
Warren,	'50				'18	'28						'41	42				'35		1'09								[illegible]		[illegible]			[illegible]
West Newton,	1'12			'03									06				'17												[illegible]	[illegible]		[illegible]
Potomac Basin.																																
Chambersburg,						'08						'62																	[illegible]			[illegible]
McConnellsburg,																																
Lake Basin.																																
Erie,†						'06					'20	'36				'26	'08	'24										[illegible]	[illegible]			[illegible]

† U. S. Weather Bureau Stations. * Missing.

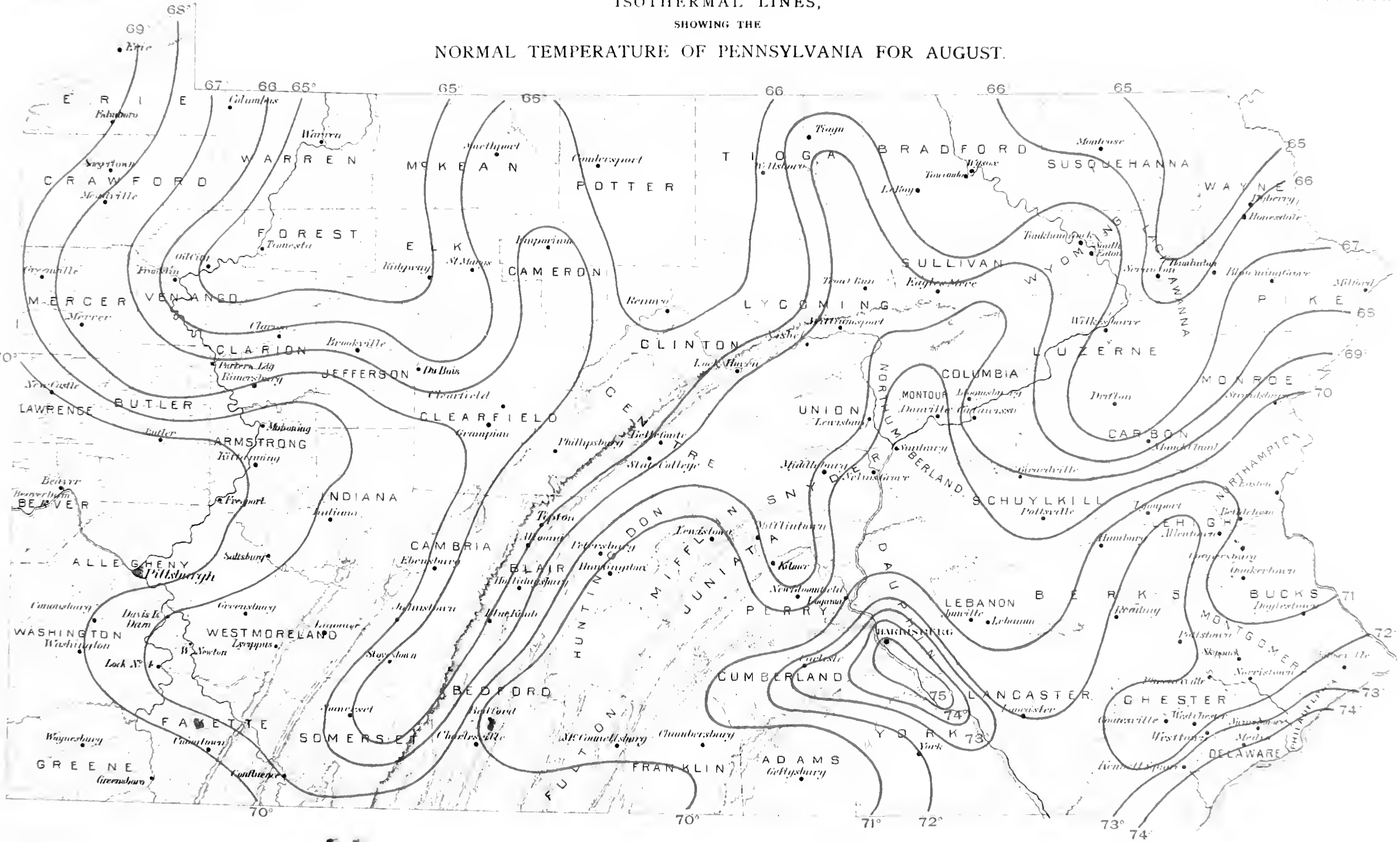
MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR AUGUST. 1893



ISOTHERMAL LINES,

SHOWING THE

NORMAL TEMPERATURE OF PENNSYLVANIA FOR AUGUST.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

H. L. BALL, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR SEPTEMBER, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 30, 1893.

GENERAL REVIEW.

September's normal temperature is about 63°·1, and its normal rainfall 3·53 inches. The present month opened decidedly cool, light frosts occurring in elevated regions on the 2d and 3d. From this time until the 25th, the temperature ranged not far from the normal, excepting a few days of warm weather about the 20th. A decidedly cool wave overspread the State on the 25th, after which cool weather continued till the close of the month.

Throughout the Delaware and Susquehanna basins, excepting the mountain and valley districts along the lower Susquehanna, the rainfall was evenly distributed, though slightly below the normal. A marked deficiency of precipitation occurred in the Ohio, Lake and Potomac basins, the deficiency amounting at most stations to one and a half or two inches. Severe local storms occurred on the 7th and 15th, the latter accompanied by general rains throughout the State. That of the 7th was particularly severe in the northern counties, and especially so in Tioga, where great damage was done to property and not a few lives lost. Observers' reports show that the storm had the appearance of a tornado. The barograph at Emporium recorded a marked though not very great fluctuation. The storm of the 15th was more general and not so destructive, but was violent in some sections.

At Philadelphia the total excess in rainfall for the month was 0·33; at York a deficiency of 2·41; Harrisburg, deficiency, 2·77; Pittsburgh, deficiency, 0·77, and Erie, deficiency, 3·01 inches.

From January 1, 1893, to September 30, 1893, the deficiency in temperature was, at Philadelphia, 315°; York, 445°; Pittsburgh, 404°, and at Erie, 403°.

For the same period the deficiency in precipitation was, at Philadelphia, 2·99; York, 7·03; Harrisburg, 9·48, and at Pittsburgh and Erie an excess of 0·99 and 0·96 inch, respectively.

EXCESSIVE PRECIPITATION.

[*One inch in one hour, or two and one-half inches in twenty-four hours.*]

Stations.	Amount. (Inches and Hundredths.)	Time. h.	Time. m.	Date.
Philadelphia,	1·36	1	—	15th, 4.58 to 5.58 p. m.
Lebanon,	2·56	3	25	15th, 2.20 p. m. to 5.45 p. m.
Coatesville,	2·51	2	30	15th, 5.00 p. m. to 7.30 p. m.
Hamburg,	2·81	—	—	15th, time not given.
Dyberry,	1·00	0	30	15th, 1.40 p. m. to 2.10 p. m.

	Mean Temperature.	*Mean Precipitation. Inches.*
September, 1888,	59°·0	4·84
1889,	61°·9	5·05
1890,	62°·0	4·57
1891,	66°·4	2·39
1892,	62°·3	2·81
1893,	60°·9	2·67

TEMPERATURE.

The mean temperature for September, 1893, was 60°·9, which is 2°·02 below the normal, and 1°·4 below the corresponding month of 1892.

The mean of the daily maximum and minimum temperatures, 71°·7 and 50·7, gives a monthly mean of 61°·2, with an average daily range of 21°·0.

Highest monthly mean, 66°·0 at Philadelphia. [Weather Bureau.]

Lowest monthly mean, 53°·2 at Wellsboro.

Highest temperature recorded during the month, 90° on the 5th at Huntingdon, on the 19th at Carlisle, and on the 19th and 20th at Somerset.

Lowest temperature, 26° on the 29th at New Castle, and on the 30th at Huntingdon.

Greatest local monthly range, 63° at Hollidaysburg.

Least local monthly range, 41° at Coopersburg.

Greatest daily range, 45° at Huntingdon on the 22d.

Least daily range, 2° at Chambersburg, on the 13th.

BAROMETER.

The mean pressure for the month, 30·04, is about ·04 below the normal. At the United States Weather Bureau Stations, the highest observed was 30·38 at Harrisburg on the 27th, and the lowest 29·64 at Philadelphia on the 16th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for September, 1893.

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level. Mean.	Highest.	Lowest.	Temperature. Mean.	Maximum. Highest.	Date.	Minimum. Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Greatest.	Date.	Least.	Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
Allegheny,	Pittsburgh, A.	820	30·04	30·33	29·80	65·0	88	19	35	29	74·8	55·8	19·0	33	21	8	12	67·2	52·2	1·86	...	...	6	15	10	5	SE	...	SE	O. D. Stewart, Weather Bureau.
Berks,	Hamburg,	380	...	...	...	62·4	86	5	37	28	73·0	51·9	21·1	36	5	7	16	...	...	5·59	...	...	7	4	17	9	NW	...	NW	William Shope.
Berks,	Reading, A.	280	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·63	...	...	...	...	...	...	...	...	...	Franklin Yager.
Blair,	Altoona, B, (28 days),	1,181	...	...	...	63·9	85	6, 8	33	27	74·4	53·4	21·0	39	22	4	13	...	...	1·85	...	...	8	...	...	...	...	...	...	Dr. C. B. Dudley.
Blair,	Blue Knob, A,	2,500	...	...	...	58·8	80	5	34	26, 29	65·5	52·2	13·3	24	21	4	13	...	...	2·76	...	...	8	7	13	10	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg,[1]	947	...	...	...	64·5	80	5	26	30	73·4	46·7	26·7	40	3, 21	9	12	...	...	1·92	...	...	9	13	8	9	S	W	W	Prof. J. A. Stewart.
Bradford,	Wysox[1],	718	30·06	30·35	29·61	58·6	83	5	32	30	68·9	46·5	22·4	37	3	9	14	81·6	51·0	2·69	...	...	10	8	10	13	NW	SE	NW	Charles Brenner.
Bradford,	Le Roy,	1,400	...	...	...	58·5	78	5	36	27	67·4	49·7	17·7	32	27	10	6, 14, 20	...	...	2·70	...	...	10	2	19	9	SW	SW	SW	G. W. T. Warburton.
Bucks,	Forks of Neshaminy[1] (29 days),	304	...	...	...	62·6	...	...	...	...	...	...	...	...	...	...	...	...	...	3·51	...	...	8	11	12	6	W	W	W	J. C. Hilsman.
Bucks,	Quakertown,[1]	530	30·03	30·35	29·69	60·1	86	19	35	28	72·2	50·1	22·1	34	5	7	8	82·9	55·2	3·67	...	...	8	9	13	8	NE	NW	W	J. L. Heacock.
Cambria,	Johnstown, A,	1,184	30·08	30·36	29·83	65·9	89	7	32	30	74·7	57·1	17·6	40	5	8	12	...	...	2·26	...	...	11	5	15	10	...	...	S	E. C. Lorentz.
Cameron,	Emporium, A (26 days),	1,050	30·06	30·41	29·74	59·6	84	7	34	29, 30	69·6	49·6	20·0	36	7	7	13	90·7	52·7	2·10	...	...	10	6	13	11	NW	...	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	...	...	...	59·7	83	5, 19	35	28	70·8	48·6	22·2	39	22	5	14	...	...	3·85	...	...	8	16	6	8	W	W	W	F. C. Wintermute.
Centre,	State College— Agricultural Experiment Station,	1,191	30·01	30·30	29·71	60·0	87	5	30	27	69·0	47·7	21·3	43	5	7	12	75·9	52·1	2·22	...	...	11	4	15	11	W	W	W	Prof. Wm. Frear.
Chester,	West Chester,[1]	455	30·05	30·30	29·70	62·9	86	19	41	30	72·5	54·7	17·8	27	22	6	14	69·7	53·3	2·58	...	...	8	14	8	5	NW	W, NW	NW	J. C. Green, D. D. S.
Chester,	Coatesville,[1]	380	...	...	...	59·1	89	19	36	20	75·3	50·4	24·9	40	22	9	14	...	...	3·67	...	...	7	10	12	8	W	W	W	W. T. Gordon.
Chester	Kennett Square, A,[2]	275	...	...	...	64·3	88	19	39	28	75·4	53·3	22·1	34	22	8	14	...	...	4·24	...	...	9	12	9	9	N	...	SW	B. P. Kirk.
Chester,	Phœnixville, A,	190	30·07	30·34	29·66	64·2	87	19	39	28	74·4	54·0	20·4	33	22	8	14	78·3	52·1	3·01	...	...	8	13	4	13	NW	...	NW	Knowles Croskey.
Chester,	Westtown (20 days),	330	...	...	...	60·8	...	...	...	...	...	...	...	...	...	...	...	...	...	1·35	...	...	...	...	...	...	...	...	...	Harry Alger.
Clearfield,	Grampian (26 days),*[1]	1,450	...	...	...	59·2	82	5, 19	32	27	68·7	51·6	17·1	34	21	6	13	...	...	3·21	...	...	8	...	17	9	W	SW	NW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	...	...	...	60·3	89	5	33	30	73·1	48·7	24·4	41	5	5	15, 23	...	...	3·70	...	...	9	8	9	13	W	W	W	Prof. J. A. Robb.
Columbia,	Bloomsburg, A— State Normal School,	500	...	...	...	60·3	84	5	37	30	70·2	50·5	19·7	34	5	7	14	88·8	54·3	2·65	...	...	9	10	14	6	W	...	NW	Prof. J. G. Cope.
Crawford,	Meadville (27 days)— Divinity Hall,[1]	1,200	...	...	...	60·6	84	7, 15	31	29	72·2	49·0	23·2	36	2	12	12	...	...	0·57	...	...	2	4	18	5	S	S	S	Chas. Graves.
Crawford,	Saegertown, A,	1,200	...	...	...	59·7	86	5, 15	28	28	71·7	47·7	24·0	38	9	8	8	...	...	0·72	...	...	7	11	13	6	SW	...	SW	J. G. Apple.
Cumberland,	Carlisle,[1]	480	...	...	...	62·0	90	19	34	30	75·2	51·8	23·4	39	22	5	15	...	...	2·[illegible]6	...	...	9	8	13	9	Calm	SW	Calm	J. E. Pague.
Dauphin,	Harrisburg, A,	361	30·06	30·38	29·71	63·0	86	19	41	27	71·3	55·4	15·[illegible]	32	22	6	11	79·0	55·0	1·74	...	...	10	9	9	12	W	...	W	F. Ridgway, Weather Bureau.
Delaware,	Swarthmore, A— Swarthmore College,	190	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Susan J. Cunningham.
Erie,	Edinboro,*[1]	1,420	...	...	...	58·9	80	7, 15	35	28	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. F. Sweet.
Erie,	Erie, A,	681	30·02	30·29	29·78	62·0	86	7	42	30	68·0	55·0	13·0	29	21	6	5	71·0	51·0	1·13	...	...	7	5	16	0	SW	...	SW	P. Wood, Weather Bureau.
Fayette,	Uniontown,[1]	1,000	...	...	...	64·4	87	7	32	29	74·5	54·4	20·1	31	3	8	11	...	...	1·30	...	...	7	22	4	4	NW	NW	W	Wm. Hunt.
Franklin,	Chambersburg,[2]	613	...	...	...	65·0	87	20	37	30	74·9	55·2	19·7	37	24	2	13	...	...	2·30	...	...	7	19	4	7	NE	SW	SW	G. W. Ludwig.
Fulton,	McConnellsburg,[1]	875	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T. F. Sloan.
Huntingdon,	Huntingdon, A— The Normal College,	650	...	...	...	61·0	90	5	32	30	73·3	48·7	24·6	45	22	8	12	...	...	3·50	...	...	10	14	5	11	W	...	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker.
Juniata,	Kilmer,[3]	475	...	...	...	63·1	88	5	38	30	...	...	...	...	...	...	...	...	...	2·90	...	...	9	2	15	13	W	W	W	R. J. McKey.
Lancaster,	Lancaster, A— Franklin and Marshall College,	413	30·09	30·34	29·69	63·4	87	2, 19	36	28	75·2	51·7	23·5	38	22	11	11	81·1	53·5	2·78	...	...	7	14	9	7	W	...	W	W. E. Bushong.
Lawrence,	New Castle,[1]	932	...	...	...	64·8	88	7, 15, 19	26	29	73·7	47·4	26·3	41	4, 21	9	25	...	...	2·07	...	...	5	9	11	10	SE	W	W	Wm. T. Butz.
Lebanon,	Lebanon, A,	458	30·05	30·32	29·68	62·3	88	19	35	28	73·7	50·8	22·9	36	22	8	14	89·6	56·2	3·79	...	...	11	9	13	8	SW	...	NE, NW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,[1]	520	...	...	...	60·4	80	19	39	28	68·9	53·1	15·8	29	22	6	23	...	...	3·23	...	...	8	10	11	9	NE	NW	NE	Dr. M. H. Boye.
Luzerne,	Drifton (26 days), A,	1,683	30·03	30·31	29·65	57·4	80	5	30	27	68·1	40·7	21·4	35	4	8	14	82·0	57·0	4·19	...	...	7	4	11	11	...	...	...	J. R. Wagner.
Luzerne,	Wilkes-Barre, A,	575	...	...	...	60·3	85	19	32	30	72·5	48·1	24·4	28	22	11	14	...	...	3·74	...	...	10	15	3	12	W	...	W	A. W. Betterly.
McKean,	Smethport, A,	1,500	...	...	...	57·8	83	7	31	28	69·1	46·4	22·7	36	3	8	16	...	...	2·92	...	...	9	3	17	1[illegible]	SE	...	W	Armstrong & Brownell.
Montgomery,	Pottstown,	150	...	...	...	63·6	86	19	40	28, 30	73·5	53·8	19·7	36	22	6	15	78·0	55·0	3·69	...	...	9	16	8	6	NW	NW	NW	Charles Moore, D. D. S.
Montgomery,	Skippack, A (26 days),	...	...	...	...	62·1	83	5, 19	38	30	73·2	51·0	22·2	35	22	7	20	...	...	2·94	...	...	7	9	10	7	W	...	W	B. W. Dambly.
Northampton,	Easton[1]— Lafayette College,	325	...	...	...	60·4	82	19	37	30	70·2	50·7	19·5	30	25	10	14	...	...	2·92	...	...	6	7	14	9	...	...	...	J. W. Moore.
Perry,	(Aqueduct) Logania,*[1]	367	...	...	...	62·0	89	5	38	27, 30	...	...	...	...	...	...	...	...	...	2·06	...	...	10	11	14	5	N	...	N	Richard Caum.
Philadelphia,	U. S. Weather Bureau, A,	117	30·05	30·33	29·64	66·0	87	19	44	30	73·8	57·7	16·1	26	2[illegible]	6	26	70·0	53·0	3·76	...	...	10	10	9	11	NW	...	NW	L. M. Dey, Weather Bureau.
Philadelphia,	1529 Centennial Avenue, A,	120	30·06	30·34	29·64	65·7	85	19	43	30	74·2	57·2	17·0	27	4	7	23	74·3	53·8	3·96	...	...	9	11	10	9	NW	...	NW	John Comly.
Philadelphia,	5911 Locust Street, A,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ralph L. Paddock.
Pike,	Blooming Grove,*[1]	...	...	...	...	55·2	83	5	37	27, 30	...	...	...	...	...	...	...	...	...	2·61	...	...	7	...	...	...	...	...	...	John Grathwohl.
Schuylkill,	Girardville[1],	1,000	30·00	30·29	29·59	59·2	82	19	35	30	68·4	50·5	17·9	32	5, 22	0	[illegible]	...	...	3·10	...	...	9	10	12	8	NW	NW	NW	E. C. Wagner.
Snyder,	Selins Grove, A,	455	30·03	30·24	29·84	63·2	89	5	32	30	75·2	51·2	24·0	38	3[illegible]	10	1[illegible]	9[illegible]·2	58·6	3·12	...	...	5	...	21	0	SW	...	SW	I. M. Boyer.
Somerset,	Somerset,[1]	2,250	...	...	...	59·9	90	19, 20	29	30	74·6	48·[illegible]	20·4	43	5	10	12	...	...	3·26	...	...	6	9	7	14	SW	SW	SW	W. M. Schrock.
Tioga,	Wellsboro,*	1,327	...	...	...	53·2	78	5	28	27	...	...	...	...	...	...	...	...	...	2·03	...	...	7	3	13	14	N	...	W	H. D. Deming.
Union,	Lewisburg, A,	450	30·06	30·35	29·83	60·2	87	19	34	30	72·2	48·2	24·0	39	3	9	13	92·2	52·0	1·74	...	...	10	13	10	7	S	...	W	Prof. W. G. Owens.
Warren,	Columbus,	1,410	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. Loveland.
Wayne,	Dyberry,[1]	1,100	...	...	...	53·4	80	5	28	27	67·2	43·0	24·2	38	3, [illegible]	6	14	...	...	3·58	...	...	9	5	16	0	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,[1]	1,[illegible]00	...	...	...	55·9	76	5	34	27, 28	65·8	46·1	19·7	29	5	9	2[illegible]	...	...	2·83	...	...	9	...	...	...	...	...	...	John Torrey.
Wayne,	(Salem Corners) Hamlinton,[1]	1,600	...	...	...	55·9	79	6, 7	33	27	67·5	48·0	19·5	33	6	8	14	...	...	2·82	...	...	11	3	17	10	NW	NW	NW	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,*[1]	1,420	...	...	...	62·6	82	7	42	29	...	...	...	...	...	...	...	...	...	1·57	...	...	7	...	...	...	...	...	...	Murray Forbes.
Westmoreland,	Ligonier (22 days),	1,750	...	...	...	59·8	87	6	28	29	73·4	46·8	26·6	43	4	8	1[illegible], 6	...	...	2·84	...	...	4	10	9	3	...	...	...	J. T. Ambrose.
Wyoming,	South Eaton, A,	660	...	...	...	58·0	80	5	36	27	67·9	48·1	19·8	30	22	7	11	...	...	2·21	...	...	8	13	7	1[illegible]	NW	...	NW	R. M. Hall.
York,	York, A,	385	30·03	30·29	29·81	63·3	89	19	36	28	74·9	51·8	23·1	39	2[illegible]	10	11	8[illegible]·3	57·4	1·57	...	...	8	11	11	8	NW	...	NW	Mrs. L. H. Grenewald.

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean of 8 + 8 ÷ 2. [3] Mean of 7 + 7 ÷ 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings.

Fro
ture wa
403°.
For
2·99; Y
0·99 an

Philadelp
Lebanon,
Coatesvill
Hamburg
Dyberry,

Septem

The
the nor
The
50·7, gi
Hig
Low
Hig
don, or
Low
Huntin
Gre
Lea
Gre
Lea

The
At the
30·38 a
16th.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,	.06						.71								1.13	.11			.15				.14		.31							2.61
Browers Lock,	.23	.08						.22						.26	.08	1.87			.14							.53						3.41
Coatesville,	.28					.01		.03						.46	2.51							.09			.29							3.67
Coopersburg,	.33						.50							.57	1.10	.46			.07				.03		.17							3.23
Doylestown,	.24						.34							.59	1.18	.45			.02						.23							3.05
Dyberry,							.71							.15	1.60	.28		.07	.17				.09		.46			.05				3.58
Easton,		.25						.71								1.55			.12				.02		.27							2.92
Forks of Neshaminy,	.35						.47							.60	1.18	.31			.12				.01		.47							3.51
Frederick,	.30						.57							.38	1.33	.19			.05						.30							3.10
Hamburg,	.48						1.30								2.81	.31			.08				.04		.57							5.59
Honesdale,	.04						.58							.16	1.17	.19	.02		.19				.08		.40							2.83
Kennett Square,	.30	.03				.07								.84	1.92	.02			.07				.20		.79							4.24
Lansdale,	.35						.65							.43	1.63				.25						.21							3.52
Mauch Chunk,	.06							.78						.43	1.33	.60		.10					.01		.54							3.85
Ottsville,	.26	.05					.63							.28	.98	.64			.08				.05		.07							3.04
Philadelphia, a†	.24	.04											.01	.42	1.95	.24			.09	.02			.01		.74							3.76
Philadelphia, b,	.30	.05												.55	1.81	.23			.09	.01					.91	.01						3.96
Philadelphia, c,																																
Phœnixville,	.26	.02						.24						.37	1.68	.05									.38	.01						3.01
Point Pleasant,	.24						.56							.45	.99	.46			.08						.23							3.01
Pottstown,	.25						.87							.30	1.85	.18			.04	.03		.02			.15							3.69
Quakertown,	.36	.03					.48							.53	1.53	.60			.07						.07							3.67
Reading,	.20					.01		.88						.19	2.18	.30			.04				.01		.02							3.83
Salem Corners,		.07					.80							.16	.06	1.04		.07	.25				.02	.11	.12	.12						2.82
Seisholtzville,	.31						.48							.48	1.32	.42									.18							3.19
Skippack,	.28	*					.64		*	*	*			.32	.99	.27			.06						.38							2.94
Smith's Corner,	.25	.03					.60							.44	.98	.48			.08						.23							3.09
Swarthmore,																																
West Chester,	.34	.01						.02						.15	1.72							.07			.26	.01						2.58
Westtown,	*	*	*	*	*	*	*	*	*	*				.25	1.10																	1.35
Susquehanna Basin.																																
Altoona,						.62		.01					.18	.34		.12					*		.20	.13	.25	*						1.85
Aqueduct,					.28	.45	.09					.02	.42	.30	.64	.07							.10		.28							2.66
Bloomsburg,							.29	.02						.14	1.75	.04		.02					.14	.01	.24							2.63
Blue Knob,						.64						.13		.80	.03	.02						.28	.26		.60							2.76
Carlisle,	.01					.47							.48	.96	.08	.21						.04			.20	.11						2.56
Drifton,		.13	*				1.24			*				1.00	1.00	.22	*							*	.45	.15						4.19
Emporium,		.10		.02			.35						.28	.06	.30			.05	.08				.32		.54							2.10
Girardville,							.63						.10	.19	1.29	.30		.04	.08				.04		.43							3.10
Grampian,	*	*	*	*	1.12		.36					.12	.11	.32	.03								.35		.80							3.21
Harrisburg,†	.03		.02		.50		.06					.15	.59	.09	.21								.04		.07							1.74
Hollidaysburg,						.50	.12					.18	.32	.13	.08	.06							.31		.22							1.92
Huntingdon,						1.14	.51					.13	.25	.30	.46	.07			.01				.45		.18							3.50
Kilmer,				.01	.25	.33							.22	.61	1.00	.06							.06		.36							2.90
Lancaster,	.87					.20								.37	.85	.12						.12			.25							2.78
Lebanon,	.10					.10	.20	.04					.03	.17	2.56	.39			.02				.06		.12							3.79
Le Roy,							.90						.05	.10	.80	.05		.12	.20				.22		.23				.03			2.70
Lewisburg,							.27						.22	.18	.13	.36		.02	.01				.21	.30	.04							1.74
Lock Haven,					.03		.83						.30	.14	1.43	.06			.01				.30		.60							3.70
Selins Grove,							.74							.15	1.79	.10									.34							3.12
South Easton,							.67							.06	.90	.07		.06					.06		.32				.07			2.21
State College,						.24	.02					.17	.24	.08	.28	.04			.01				.32	.01	.81							2.22
Wellsboro,							1.20						.02		.36			.05	.20				.08		.12							2.03
Wilkes-Barre,		.05					1.53							.03	1.02	.16		.05		.48			.16		.20				.06			3.74
Wysox,							1.25					.04	.04	.48			.41					.18	.22	.03			.14	.10				2.89
York,	.10					.27							.23	.11	.41	.11						.19			.15							1.57

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,																																[illegible]
Brookville,						.53		.82			.07		.04	.11	.08				.02					.21	.12	.06						[illegible]
Clarion,		.08				.70		.05				.01	.11	.38	.01				.14					.40	.60	.05						[illegible]
Columbus,																																
Confluence,		.05						.80				.01	.05	.55						.04			.10	.03	.30	.53						[illegible]
Davis Island Dam,														.40						.24			.33	.30	.35	.04						[illegible]
DuBois,						.60		.19					.04	.18	.24				.08					.53	.75							[illegible]
Freeport,						.50						.01	.05	.55									.13	.52	.57	.04						[illegible]
Greensboro,												.06	.02	.15									.25	.05	.15	.50						[illegible]
Immel Reservoir,							.27							.25		.12						.07	.15		.61				.10			[illegible]
Indiana,																																
Johnstown,				.01	.01	.42	.37					.09	.03	.40		.05						.18	.25		.41							[illegible]
Ligonier,							1.22	*	*					.64						*	*	*	.36	*	*	.60						[illegible]
Lock No. 4,														.16		.06				.06			.22	.22	.38							[illegible]
Mahoning,						1.03							.08	.30		.03			.04				.11	.55	.55	.05						[illegible]
Meadville,						.29																	.25	*	*							[illegible]
New Castle,						.52						.20											.46		.34					.35		[illegible]
Oil City,						.61						.03	.05	.40					.09					.47	.57	.07						[illegible]
Parker's Landing,						.71		.01					.09	.52	.13				.02					.45	.60							[illegible]
Pittsburg,†												.02	.01	.23					.20			.40	.32		.65					.03		[illegible]
Ridgway,						.36	.05						.25	.15				.15				.30		.60								[illegible]
Saegertown,		.10			.03		.25					.01							.21				.03		.09							[illegible]
Saltsburg,						.20		.02				.01	.02	.13									.47	.43	.53							[illegible]
Smethport,				.02			.05							.15	1.30			.20	.15			.10	.35		.60							[illegible]
Somerset,							.75					.06		1.20					.18				.15		.92							[illegible]
Stoyestown,								.40								.60							.41	.30	.43							[illegible]
Uniontown,												.02	.06	.15								.12	.02		.86					.07		[illegible]
Warren,		.06						.03					.04		.04	.05	.11		.31	.17		.05		.25	.08	.09						[illegible]
West Newton,													.02	.10		.01				.01			.13	.10	.40	.02						[illegible]
Potomac Basin.																																
Chambersburg,					.51							.27	1.10	.08	.23								.08	.03								[illegible]
McConnellsburg,																																
Lake Basin.																																
Erie,†												.02			.17	.14		.06	.45				.05		.24							[illegible]

† U. S. Weather Bureau Stations. * Missing.

tur
40

2·9
0·9

—

—

Phi
Leb
Coa
Har
Dyl

—

Sep

the

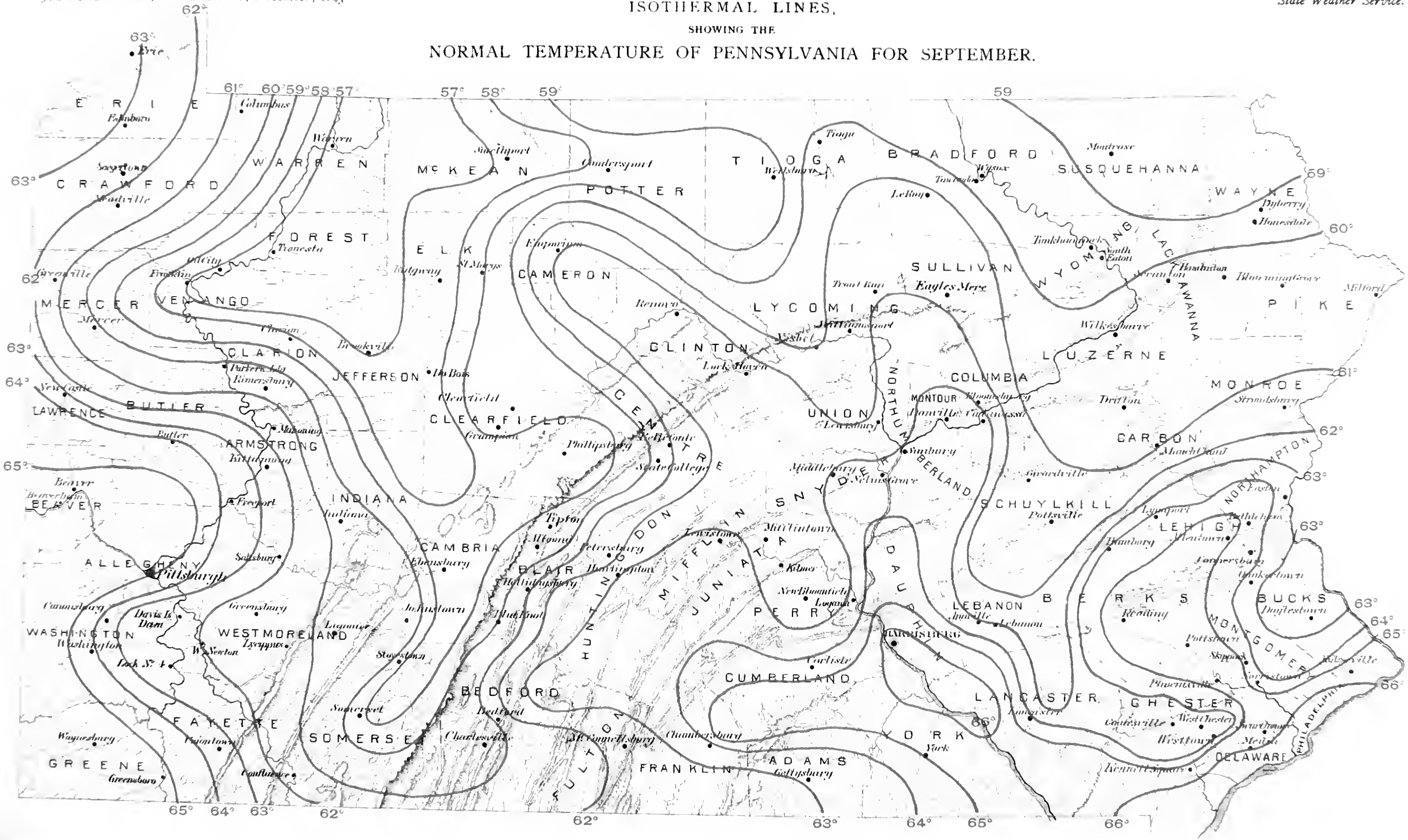
50·

do

Hu

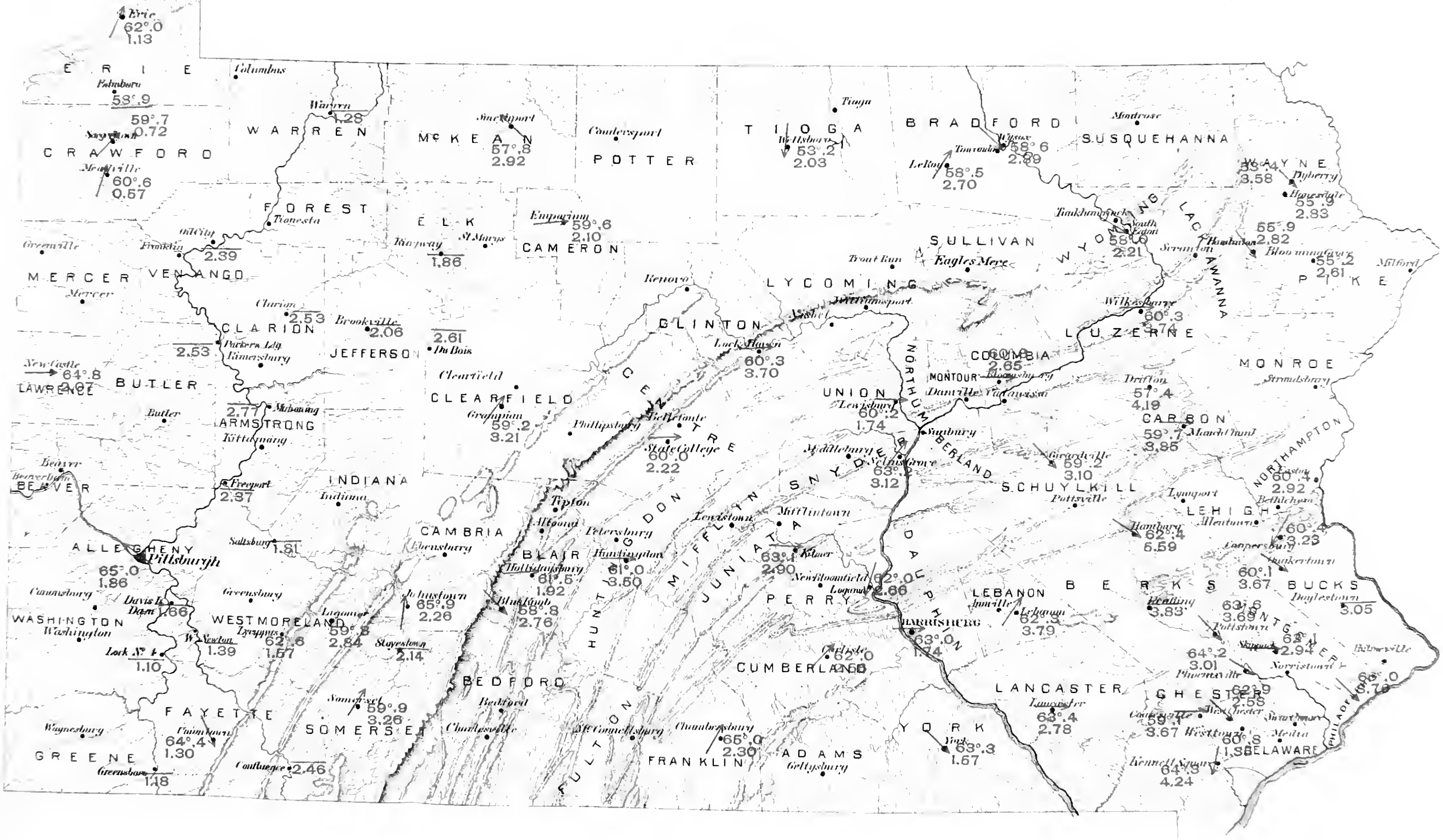
At
30·
16

ISOTHERMAL LINES,
SHOWING THE
NORMAL TEMPERATURE OF PENNSYLVANIA FOR SEPTEMBER.



tur
40.
2·9
0·9
—
—
Ph
Le
Co
Ha
Dy
—
Se
th
50
d
F
A
3
1

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR SEPTEMBER. 1893



Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for October, 1893.

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level: Mean.	Barometer: Highest.	Barometer: Lowest.	Temperature: Mean.	Maximum: Highest.	Maximum: Date.	Minimum: Lowest.	Minimum: Date.	Mean of Maximum.	Mean of Minimum.	Daily Range: Mean.	Daily Range: Greatest.	Daily Range: Date.	Daily Range: Least.	Daily Range: Date.	Relative Humidity.	Dew Point.	Precipitation: Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Number of Days: Clear.	Fair.	Cloudy.	Prevailing Wind Direction: 7 A. M.	2 P. M.	9 P. M.	Observers.
Allegheny,	Pittsburgh, A.	[illegible]	[illegible]	30.53	29.17	55.[illegible]	[illegible]	11	29	1	65.6	45.[illegible]	[illegible]	39	3	[illegible]	15	72.9	44.6	3.22	...	...	10	17	4	10	SE	SE	SE	[illegible] Weather Bureau.
Berks,	Hamburg	350	...	...	...	54.[illegible]	[illegible]	9	[illegible]	1	64.[illegible]	44.[illegible]	[illegible]	38	9, 17	[illegible]	4	...	...	3.57	...	...	6	[illegible]	14	7	E	...	...	[illegible]
Berks,	Reading, A	[illegible]	...	...	...	52.[illegible]	...	...	...	...	...	...	...	...	...	...	...	...	...	3.16	...	...	10	...	...	...	...	...	...	[illegible] Yeager
Blair,	Altoona, B, (28 days),	1,181	...	...	...	55.[illegible]	[illegible]	10	33	1	[illegible]	47.3	16.7	29	9	5	[illegible]	...	...	2.71	...	...	10	...	...	...	...	...	...	Dr. C. B. Dudley
Blair,	Blue Knob, A,	[illegible]	...	...	...	4[illegible]	[illegible]	9, 11	15	1	[illegible]	42.8	12.7	31	2	2	15	...	...	6.55	T	...	11	11	10	[illegible]	NW	NW	NW	A. H. Boyle
Blair,	Hollidaysburg,	947	...	...	...	51.[illegible]	[illegible]	9	17	1	[illegible]	36.4	28.2	50	2	1	15, 2[illegible]	...	...	[illegible].93	...	...	[illegible]	16	9	[illegible]	W	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	[illegible]	30.11	30.51	29.12	50.[illegible]	[illegible]	10	22	31	62.[illegible]	39.4	22.6	48	11	...	24	85.0	46.3	1.3	...	...	6	15	2	4	S	NW	NW	Charles Beecher
Bradford,	Le Roy,	1,400	...	...	...	52.[illegible]	[illegible]	11	24	31	61.3	42.7	15.0	37	11	3	[illegible]	...	...	3.91	T	...	10	11	10	[illegible]	SW	SW	SW	G. W. T. Warburton
Bucks,	Forks of Neshaminy (30 days),	304	...	...	...	53.4	...	...	...	...	...	...	...	...	...	...	...	...	...	3.35	...	...	[illegible]	12	10	[illegible]	W	E	E	[illegible]
Bucks,	Quakertown,	530	30.13	30.54	29.29	52.[illegible]	73	2	21	31	6[illegible].7	42.0	21.7	37	1[illegible]	7	4	82.9	47.1	3.33	T	...	7	14	11	6	NW	NW	NW	J. L. Heacock
Cambria,	Johnstown, A (20 days),	1,184	30.14	30.60	28.92	54	75	11	...	...	69.7	4[illegible]	29.6	...	...	...	...	...	...	3.22	T	...	11	9	14	8	S	...	[illegible]	E. C. Lorentz.
Cameron,	Emporium, A,	1,052	30.[illegible]	30.02	29.09	52	70	11	24	1	63.5	4[illegible]	23.0	44	11	6	15, 31	91.7	44.7	[illegible].36	T	...	12	13	5	13	NW	...	E	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	55[illegible]	...	...	...	52.[illegible]	80	9	[illegible]	31	[illegible]	42.6	2[illegible].5	4	15	3	4	...	...	2.14	T	...	7	13	10	[illegible]	E	E	E	F. C. Wintermute
Centre,	State College—Agricultural Experiment Station,	1,191	30.05	30.52	29.11	52.[illegible]	70	8	[illegible]	31	[illegible].4	4[illegible]	2[illegible].5	34	8	6	23	75.3	44.1	3.23	...	...	1[illegible]	11	7	1[illegible]	S	S	S	Prof. Wm. Frear.
Chester,	West Chester,	455	30.10	30.42	29.25	54.[illegible]	[illegible]	9	[illegible]	31	[illegible].7	46.9	16.8	[illegible]	17	5	4	73.0	47.0	[illegible].45	...	...	9	1[illegible]	4	8	NW	E	E	J. C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	53.[illegible]	81	9	...	31	67.7	42.6	25.1	47	9	6	4	...	...	4.0[illegible]	...	...	9	16	6	9	W	W	W	W. T. Gordon
Chester,	Kennett Square, A,	275	...	...	...	55.[illegible]	84	9	...	31	66.8	44.8	22.[illegible]	37	9, 17	6	4	...	...	2.[illegible]7	...	...	10	19	2	1[illegible]	NW	...	NW	B. P. Kirk
Chester,	Phoenixville, A,	190	30.17	30.56	29.30	55.[illegible]	73	[illegible]	...	31	65.5	45.9	19.6	36	9	5	4	77.7	47.4	3.4[illegible]	...	...	1[illegible]	11	7	13	NW	...	NW	Knowles Croskey.
Chester,	Westtown (28 days),	350	...	...	...	54	80	10	[illegible]	31	6[illegible].6	44.5	19.1	34	10	6	5	...	...	...	...	...	6	15	[illegible]	[illegible]	W	...	W	Harry Alger.
Clearfield,	Grampian (30 days),	1,450	...	...	...	49.[illegible]	76	11	1[illegible]	31	6[illegible]	40.9	1[illegible].1	44	2	2	15	...	...	2.62	...	...	6	12	11	7	W	W	SW	Nathan Moore
Clinton,	Lock Haven,	500	...	...	...	54	[illegible]3	9	...	31	6[illegible].7	39.4	27.3	47	2	5	4	...	...	2.67	...	...	9	16	5	1[illegible]	W	W	W	Prof. J. A. Robb.
Columbia,	Bloomsburg, A—State Normal School,	500	30.25	[illegible].43	29.49	53.[illegible]	70	9	4	31	63.8	4[illegible]	21.0	35	2	9	16, 2[illegible]	81.8	46.2	1.18	...	...	8	14	8	9	W	...	N	Prof. J. G. Cope.
Crawford,	Meadville—Divinity Hall,	1,200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Chas. Graves
Crawford,	Saegertown, A,	1,200	...	...	...	50.[illegible]	[illegible]	2[illegible]	...	31	[illegible]	36.0	29.5	51	11	7	1[illegible]	...	...	3.00	0.2	...	[illegible]	13	9	9	S	...	SW	J. G. A[illegible]
Cumberland,	Carlisle (19 days),	450	...	...	...	53.[illegible]	55	9	3	31	66.7	42.4	24.3	40	[illegible]	6	4, 2[illegible]	...	...	[illegible].97	...	...	4	11	4	4	Calm	SW	W	J. E. Page
Dauphin,	Harrisburg, A,	361	30.1[illegible]	30.52	29.26	55.[illegible]	[illegible]2	9	[illegible]	31	63.0	47.0	16.0	32	[illegible]	4	4	82.0	48.0	3.23	...	...	9	13	7	11	W	W	W	F. Ridgway, Weather Bureau.
Delaware,	Swarthmore, A—Swarthmore College,	190	30.11	30.44	29.29	56.[illegible]	[illegible]	[illegible]	27	31	64.9	48.2	16.7	2[illegible]	17	5	23	[illegible]4	41.0	3.35	...	...	4	11	1[illegible]	7	NW	...	NW	Prof. Susan J. Cunningham
Erie,	Edinboro,	1,400	...	...	...	50.4	76	11	4	31	...	...	...	...	...	...	...	...	...	...	...	...	...	17	4	10	W	...	...	C. F. [illegible]
Erie,	Erie, A,	681	30.05	30.30	29.05	54	84	12	...	31	62.0	46.0	16.0	28	3	4	27	70.0	42.[illegible]	3.54	...	...	10	12	7	12	S	S	S	P. W[illegible]d, Weather Bureau.
Fayette,	Uniontown (26 days),	1,000	...	...	...	56.[illegible]	[illegible]1	12	29	17	66.7	45.7	21.0	35	2	5	15	...	...	3.22	...	...	6	17	[illegible]	6	SW	SW	SW	Wm. Hunt
Franklin,	Chambersburg (29 days),	618	...	...	...	54.[illegible]	80	9	[illegible]	[illegible] 31	62.9	45.8	17.1	4	9	2	5	...	...	3.85	...	...	5	19	[illegible]	7	NE	SW	SW	[illegible] W. Ludwig
Fulton,	McConnellsburg,	875	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T. F. Sloan
Huntingdon,	Huntingdon, A—The Normal College,	650	...	...	...	52.[illegible]	82	9	21	31	66.4	33.7	27.7	44	2	10	15	...	...	3.70	...	...	8	15	3	13	W	...	W	Prof. W. J. Swigart.
Indiana,	Indiana—State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker.
Juniata,	Kilmer,	475	...	...	...	53.[illegible]	75	24	28	31	...	...	...	...	...	...	...	...	...	4.41	...	...	7	13	8	10	W	...	...	R. J. M[illegible]key
Lancaster,	Lancaster, A—Franklin and Marshall College,	413	30.14	30.51	29.27	54.[illegible]	82	9	[illegible]4	31	64.7	43.9	20.8	36	18	6	4	86.0	48.3	3.30	...	...	9	19	4	8	W	...	W	W. E. Bushong.
Lawrence,	New Castle,	932	...	...	...	52.[illegible]	82	11, 12	19	31	63.5	35.6	27.9	45	2	7	15	...	...	4.59	...	...	[illegible]	13	5	13	SE	S	SW	Wm. T. Butz
Lebanon,	Lebanon, A,	458	30.14	30.52	29.08	53.[illegible]	80	9	2[illegible]	31	64.4	42.[illegible]	22.2	38	9	8	4	91.4	4[illegible].4	3.95	...	...	8	14	10	[illegible]	NW	...	NW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,	520	...	...	...	53.2	75	9	25	31	61.4	45.7	15.7	31	17	[illegible]	4	...	...	3.26	...	...	10	14	9	8	NE	SW	NE	Dr. M. H. Boye
Luzerne,	Drifton (26 days), A,	1,683	30.12	30.57	29.24	51.[illegible]	76	11	[illegible]	30	64.7	39.0	25.7	28	2, 27	7	4	79.0	47.0	3.16	...	...	4	15	6	5	...	...	...	J. R. Wagner
Luzerne,	Wilkes-Barre, A,	575	...	...	...	53.[illegible]	[illegible]2	9	21	31	66.2	41.[illegible]	24.9	43	11, 12	7	15	...	...	1.70	...	...	6	10	6	9	W	...	W	A. W. Betterly
McKean,	Smethport, A,	1,500	...	...	...	50.[illegible]	81	11	17	31	63.6	37.5	26.1	5[illegible]	11	6	4	...	...	3.05	2.0	...	6	11	6	14	SW	...	SW	Armstrong & Brownell.
Montgomery,	Pottstown,	150	...	...	...	55.5	81	9	27	31	65.4	45.7	19.7	36	9	4	4, 23	74.6	44.6	3.13	T	...	6	23	2	6	NW	W	E	Charles Moore, D.D.S.
Montgomery,	Skippack, A (25 days),	...	...	...	...	54.[illegible]	68	21	25	31	66.7	42.3	24.4	37	9	6	23	...	...	2.70	...	...	4	14	6	5	W	...	W	B. W. Dambly.
Northampton,	Easton—Lafayette College,	325	...	...	...	53.[illegible]	75	9	[illegible]4	30	61.5	43.2	1[illegible].3	28	9, 17	6	23	...	...	2.62	...	...	5	...	...	...	...	...	...	J. W. Moore
Perry,	Aqueduct (Logania),	367	...	...	...	55.[illegible]	83	9	[illegible]2	31	66.1	44.6	21.5	[illegible]7	9	[illegible]	27	...	...	3.29	...	...	11	16	7	8	NW	...	...	R[illegible]chard Call
Philadelphia,	U. S. Weather Bureau, A,	117	30.12	30.53	29.31	58.[illegible]	80	9	33	31	65.4	49.9	15.5	26	17	4	16	73.0	46.0	3.32	...	...	9	13	10	8	NW	NW	NW	L. M. Dey, Weather Bureau.
Philadelphia,	1529 Centennial Avenue, A,	120	30.12	30.53	29.31	57.4	80	9	30	31	65.6	49.2	16.4	26	17	5	4	77.0	47.2	3.50	...	...	9	15	9	7	...	...	...	John Comly
Philadelphia,	3911 Locust Street, A,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ralph [illegible] Paddock
Pike,	Blooming Grove,	...	...	...	...	49.4	76	11	2[illegible]	30, 31	...	...	...	...	...	...	...	...	...	1.51	...	...	5	...	...	...	...	...	...	John Grathw[illegible]
Schuylkill,	Girardville (29 days),	1,000	30.05	30.45	29.16	52.[illegible]	78	2, 9	[illegible]8	31	62.3	43.2	19.1	36	9	7	10	...	...	3.87	...	...	8	14	11	4	W	NW	NW	E. C. Wagner
Snyder,	Selins Grove, A,	455	30.07	30.43	29.23	52.4	75	2	26	30, 31	67.1	37.7	29.4	41	2	12	23	91.8	47.5	4.21	...	...	8	[illegible]	21	7	SW	...	SW	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	49.[illegible]	81	10	18	31	[illegible].4	38.7	24.7	42	10	10	15, 24	90.3	47.5	3.01	...	...	7	1[illegible]	...	15	NW	SW	NW	W. M. Schrock.
Tioga,	Wellsboro,	1,327	...	...	...	46.[illegible]	74	9	2[illegible]	31	58.1	36.4	21.8	41	2, 18	1	4	...	...	2.88	1.0	...	9	11	8	12	S	...	S	H. D. Dem[illegible]
Union,	Lewisburg, A,	450	30.12	...	...	52.6	82	9	22	31	64.6	40.6	24.0	45	9	7	15	92.0	48.6	3.20	...	...	10	10	10	11	S	...	S	Prof. W. G. Owens
Warren,	Columbus,	1,410	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. Loveland
Wayne,	Dyberry,	1,100	...	...	...	48.1	79	9	15	31	61.8	37.4	24.4	49	11	2	23	...	...	2.17	T	...	5	11	12	8	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	50.[illegible]	73	9	19	13	60.0	40.5	19.5	34	18	4	23	...	...	1.99	...	...	6	...	...	...	...	...	...	John Torrey
Wayne,	(Salem Corners) Hamlinton,	1,600	...	...	...	48.7	76	12	19	31	60.9	40.5	20.4	38	11	5	23	...	...	2.70	...	...	7	11	11	9	W	SE	W	T. E. Orchard, M.D.
Westmoreland,	(Immel Reservoir) Lycippus,	1,420	...	...	...	55.6	78	11	35	30	...	...	...	...	...	...	...	...	...	2.92	...	...	9	...	...	...	...	...	...	Murray Forbes
Westmoreland,	Ligonier,	1,750	...	...	...	51.5	87	11	18	31	66.0	37.4	28.6	53	11	4	14	...	...	2.98	...	...	5	20	...	11	...	...	...	J. T. Ambrose
Wyoming,	South Eaton, A,	660	...	...	...	57.[illegible]	79	9	21	31	62.4	41.5	20.9	39	11	6	4	...	...	1.88	...	...	9	12	7	12	NW	...	NW	R. M. Hall
York,	York, A,	385	30.07	30.48	28.99	54.[illegible]	82	9	22	31	65.0	43.4	21.6	40	9	7	14	86.1	48.8	3.03	...	...	8	15	5	8	NW	...	NW	Mrs. L. H. Grenewald

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean of 8 + 8 + 2. [3] Mean of 7 + 7 + 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings.

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU

T. F. TOWNSEND, WEATHER BUREAU, L. F. O. IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR OCTOBER, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 31, 1893.

GENERAL REVIEW.

October's normal temperature and rainfall is about 49°·7 and 3·47 inches. The present month has been 3° warmer than the average, and the rainfall a quarter of an inch less.

The warmest period was between the 9th and the 11th, and the coldest occurred during the last three days of the month, when killing frosts were general throughout the State.

The centre of the cyclonic storm of the 13th and 14th passed nearly due north over the central portion of the State, attended by high winds and heavy rains. A large amount of damage was done at various points to buildings, fruit and shade trees, fences and telegraph poles.

The *Philadelphia Record*, of the 14th, says: "Ample warning of the approach of yesterday's storm was given by the Weather Bureau. One such timely notification is well worth the amount of cost of the weather observation service." Heavy and general rains occurred during the month, on the 4th, 7th, 13th, 14th, 23d, 27th and 28th.

From January 1, 1893, to October 31, 1893, the deficiency in temperature was, at Philadelphia, 282°; Pittsburgh, 401°, and York, 364°.

For the same period the deficiency in precipitation was, at Philadelphia, 2·61; York, 7·24; and excess at Pittsburgh, 1·58 inches.

EXCESSIVE PRECIPITATION.

[*One inch in one hour, or two and one-half inches in twenty-four hours.*]

STATIONS.	Amount. (Inches and Hundredths.)	Time h.	Time m.	Date.
Beaver Dam,	3·44	24	—	13th, 14th.
LeRoy,	2·60	24	—	13th, 14th.
New Castle,	2·63	24	—	13th, 14th.
Swarthmore,	3·00	24	—	22d, 23d.

	Mean Temperature.	Mean Precipitation. Inches.
October, 1888,	46°·1	4·03
1889,	47°·3	3·85
1890,	50°·9	5·87
1891,	50°·4	3·06
1892,	50°·5	0·78
1893,	52°·8	3·26

TEMPERATURE.

The mean temperature for October, 1893, was 52°·8, which is 3°·1 above the normal, and 2°·3 above the corresponding month of 1892.

The mean of the daily maximum and minimum temperatures, 63°·9 and 42·2, gives a monthly mean of 53°·0, with an average daily range of 21°·7.

Highest monthly mean, 58°·0 at Philadelphia. [Weather Bureau.]

Lowest monthly mean, 46°·0 at Wellsboro.

Highest temperature recorded during the month, 91° on the 9th at Coatesville.

Lowest temperature, 17° on the 31st at Hollidaysburg and Smethport.

Greatest local monthly range, 69° at Coatesville and Ligonier.

Least local monthly range, 42° at Altoona.

Greatest daily range, 53° at Ligonier on the 11th.

Least daily range, 2° at Coopersburg, 4th; Chambersburg, 5th; Blue Knob, 15th, and Dyberry, 23d.

BAROMETER.

The mean pressure for the month, 30·10, is about ·03 above the normal. At the United States Weather Bureau Stations, the highest observed was 30·53 at Pittsburgh on the 17th, and the same at Philadelphia on the 19th, and the lowest 29·05 at Erie on the 14th.

PRECIPITATION.

The average rainfall, 3·26 inches for the month, is a deficiency of 0·22 inch.

The largest monthly totals in inches were Blue Knob, 6·58; Beaver Dam, 5·63; Stoyestown, 4·61; New Castle, 4·59; and Kilmer, 4·41 inches.

PRECIPITATION.

The average rainfall, 2·67 inches for the month, is a deficiency of 0·86 inch.

The largest monthly totals in inches were Hamburg, 5·59; Kennett Square, 4·24, and Drifton, 4·19 inches.

The least were Saegertown, 0·72; Lock No. 4, 1·10, and Erie, 1·13 inches.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 8; clear days, 9; fair days, 12; cloudy days, 9.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 5th, 6th, 7th, 15th, 16th, 22d; Hollidaysburg, 6th, 7th, 15th, 22d; Le Roy, 7th, 14th; Quakertown, 7th, 15th, 16th; Johnstown, 5th, 16th, 22d; Emporium, 5th, 7th, 15th; Mauch Chunk, 15th, 16th; State College, 7th; Coatesville, 15th, 22d, 25th; Kennett Square, 7th, 15th, 22d; Phœnixville, 7th; Lock Haven, 7th, 15th; Bloomsburg, 7th, 15th; Saegertown, 6th; Carlisle, 7th, 22d; Harrisburg, 5th, 6th, 15th, 16th; Uniontown, 22d; Chambersburg, 6th; Huntingdon, 6th, 7th, 15th; Kilmer, 5th, 6th, 15th, 16th; Lancaster, 15th; Lebanon, 7th, 15th; Drifton, 7th, 14th, 15th, 16th, 25th; Wilkes-Barre, 7th, 15th; Smethport, 7th, 15th; Pottstown, 7th, 15th; Skippack, 7th; Aqueduct, 5th, 7th, 15th; *Philadelphia*, 7th, 15th, 16th, 22d, 25th; [Centennial Avenue], 7th, 14th, 15th, 16th, 20th, 22d, 25th; Blooming Grove, 7th; Girardville, 7th, 15th, 16th; Selins Grove, 7th; Somerset, 7th, 19th; Wellsboro, 7th, 15th; Dyberry, 7th, 15th, 16th; Salem Corners, 7th, 15th; South Eaton, 7th, 15th; York, 15th, 22d.

Hail.—Blue Knob, 7th; Wysox, 7th; Emporium, 5th, 7th; Phœnixville, 7th; Lock Haven, 15th; Bloomsburg, 7th; Lebanon, 15th; Aqueduct, 15th; Blooming Grove, 7th; Girardville, 7th; Selins Grove, 7th; Dyberry, 7th, 15th.

Frost.—Pittsburgh, 27th, 28th, 29th, 30th; Blue Knob, 2d, 21st, 26th, 27th, 28th, 29th, 30th; Hollidaysburg, 30th; Wysox, 30th; Le Roy, 26th, 27th; Quakertown, 28th; Johnstown, 27th, 28th, 29th, 30th; Emporium, 29th; State College, 27th, 30th; Grampian, 26th, 27th, 28th; Lock Haven, 29th, 30th; Bloomsburg, 30th; Saegertown, 28th, 29th, 30th; Carlisle, 21st; Uniontown, 3d, 27th, 28th, 29th; Kilmer, 30th; New Castle, 25th, 26th, 27th, 28th, 29th, 30th; Lebanon, 18th, 27th, 28th; Coopersburg, 27th; Drifton, 3d, 26th, 27th; Wilkes-Barre, 28th, 29th, 30th; Smethport, 26th; Skippack, 7th, 28th, 29th, 30th; Aqueduct, 3d, 26th, 30th; Blooming Grove, 20th, 21st, 22d, 23d, 24th, 25th, 26th, 27th, 28th, 29th, 30th; Girardville, 3d, 6th, 21st, 26th, 27th, 28th, 29th, 30th; Selins Grove, 26th, 27th, 29th, 30th; Somerset, 3d, 4th, 28th, 29th, 30th; Wellsboro, 3d, 9th, 21st, 26th, 27th, 28th; Lewisburg, 30th; Dyberry, 3d, 21st, 27th, 28th, 30th; Honesdale, 3d, 26th, 27th, 28th, 29th, 30th; Salem Corners, 26th, 27th, 28th, 29th; Ligonier, 29th, 30th; York, 3d, 28th, 29th, 30th.

Snow.—Girardville, 29th.

Aurora.—Johnstown, 8th ; Coatesville, 21st ; Dyberry, 8th ; Salem Corners, 2d, 3d, 7th, 9th, 10th, 11th, 12th, 30th.

Coronæ.—Emporium, 22d, 23d ; Lebanon, 24th ; Philadelphia [Centennial Avenue], 26th ; York, 26th.

Solar Halo.—Johnstown, 26th ; Bloomsburg, 30th ; Saegertown, 30th ; *Philadelphia*, 9th, 30th ; [Centennial Avenue], 9th, 10th, 12th, 30th ; Wellsboro, 17th, 30th ; Salem Corners, 26th.

Lunar Halo.—Blue Knob, 24th ; Saegertown, 29th ; Somerset, 23d ; Wellsboro, 22d.

OCTOBER WEATHER.

From United States Weather Bureau Records.

The following data, compiled from the records of observations taken during the length of time given at each station, show the average and extreme conditions during that time, and also the range within which weather variations may be expected to keep in any future October.

	Philadelphia. (22 years.)	Pittsburgh. (22 years.)	Erie. (20 years.)
Mean or normal,	56°	54°	52°
Warmest October, Average,	1879 62°	1881 60°	1879 60°
Coldest October, Average,	1876 51°	1876 49°	1889 46°
Highest temperature recorded, Date,	87° 3d, 1879; 1st, 1881	91° 3d, 1884	85° 7th, 1879
Lowest temperature recorded. Date,	31° 30th, 1873; 16th, 1876	20° 31st, 1887	26° 26th, 31st, 1887
Average date of first "killing" frost,	28th	21st	15th
Average precipitation (inches),	2·80	2·37	4·08
Average number of days with ·01 inch or more,	10	11	16
Greatest monthly precipitation, Date,	6·52 1877	6·21 1873	8·17 1885
Least monthly precipitation, Date,	0·30 1892	0·06 1874	1·18 1879
Greatest amount in 24 hours, Date,	3·70 25th, 26th, 1872	1·96 20th, 1873	2·06 23d, 1878
Greatest amount snowfall in 24 hours, Date,	0 0	trace. 31st, 1885	·5 inch. 21st, 1887
Average number clear days, Partly cloudy, Cloudy,	12 10 9	8 12 11	7 9 15
Prevailing direction of wind,	N. W.	N. W.	S.
Highest velocity, miles per hour, Date,	75 23d, 1878	40 23d, 1887	48 24th, 1887

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for October, 1893.

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level. Mean.	Barometer Highest.	Barometer Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean	Daily Range. Greatest.	Daily Range. Date	Daily Range. Least	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction. 7 A. M.	2 P. M.	9 P. M.	Observers.
Allegheny,	Pittsburgh, A.	820	30·00	30·53	29·17	55·[illegible]	86	11	29	31	65·6	45·3	[illegible]	31	3	5	15	72·9	44·6	3·22	...	...	10	17	4	10	SE	SE	SE	[illegible] Stewart, Weather Bureau.
Berks,	Hamburg,	380	...	...	...	54·[illegible]	80	9	23	31	64·9	44·[illegible]	[illegible]	38	9, 17	5	4	...	...	3·57	...	...	6	16	14	7	E	...	...	[illegible] Shipe.
Berks,	Reading, A,	260	...	...	...	52·0	...	...	...	...	...	...	...	...	...	...	...	...	...	3·18	...	...	10	...	...	...	...	...	...	[illegible] Yager.
Blair,	Altoona, B, (25 days),	1,181	...	...	...	55·7	75	10	33	31	64·0	47·3	16·7	29	9	5	21	...	...	2·71	...	...	10	...	...	...	...	...	...	Dr. C. B. Dudley.
Blair,	Blue Knob, A,	2,500	...	...	...	49·2	70	9, 11	18	31	55·5	42·8	12·7	31	2	2	15	...	...	6·50	T	...	11	11	10	[illegible]	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg,	947	...	...	...	51·3	80	9	17	31	64·6	36·4	28·2	50	2	10	15, 2[illegible]	...	...	3·93	...	...	9	16	9	6	W	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	30·11	30·51	29·12	50·7	80	10	22	31	62·0	39·4	22·6	48	11	[illegible]	24	85·0	46·3	[illegible]	...	...	6	15	2	14	S	NW	NW	Charles Beecher.
Bradford,	Le Roy,	1,400	...	...	...	52·0	78	11	24	31	61·3	42·7	18·6	37	11	3	[illegible]	...	...	3·91	T	...	10	11	10	[illegible]	SW	SW	SW	G. W. T. Warburton.
Bucks,	Forks of Neshaminy[1] (30 days),	304	...	...	...	53·4	...	...	...	...	...	...	...	...	...	...	...	...	...	3·35	...	...	9	12	10	5	W	E	E	J. C. H[illegible]sman.
Bucks,	Quakertown,[1]	536	30·13	30·54	29·29	52·[illegible]	73	2	21	31	63·7	42·0	21·7	37	18	7	4	82·9	47·1	3·33	T	...	7	14	11	[illegible]	NW	NW	NW	J. L. Heacock.
Cambria,	Johnstown, A (20 days),	1,184	30·14	30·60	28·92	54·[illegible]	85	11	...	...	63·7	4[illegible]	20·6	...	...	...	...	...	...	3·22	T	...	11	9	14	8	S	...	S	E. C. Lorentz.
Cameron,	Emporium, A,	1,050	30·12	30·62	29·09	52·[illegible]	79	11	24	31	63·5	4[illegible]·5	23·0	41	11	6	15, 31	91·7	44·7	3·36	T	...	12	13	5	13	NW	...	E	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	...	...	...	52·[illegible]	80	9	2	31	[illegible]	42·6	[illegible]	4	10	3	4	...	...	2·94	T	...	7	13	10	8	E	E	E	F. C. Wintermute.
Centre,	State College[1]— Agricultural Experiment Station,	1,191	30·05	30·57	29·11	52·[illegible]	79	8	21	31	61·4	4[illegible]	[illegible]	32	8	6	23	75·3	44·1	3·23	...	...	10	11	7	13	S	S	S	Prof. Wm. Frear.
Chester,	West Chester,[1]	455	30·10	30·49	29·25	54·[illegible]	81	9	[illegible]	31	63·7	46·9	16·8	[illegible]	17	5	4	73·0	47·0	3·45	...	...	9	19	4	8	NW	E	E	J. C. Green, D.D.S.
Chester,	Coatesville,[1]	380	...	...	...	53·5	91	9	2[illegible]	31	67·7	42·6	25·1	47	9	6	4	...	...	4·[illegible]	...	...	9	16	6	9	W	W	W	W. T. Gordon.
Chester,	Kennett Square, A,	275	...	...	...	55·[illegible]	84	9	2[illegible]	31	66·8	44·8	22·0	37	9, 17	6	4	...	...	2·37	...	...	10	19	2	15	NW	...	NW	B. P. Kirk.
Chester,	Phœnixville, A,	190	30·17	30·56	29·30	55·[illegible]	83	9	25	31	65·5	45·9	19·6	36	9	5	4	79·7	47·4	3·49	...	...	10	11	7	13	NW	...	NW	Knowles Croskey.
Chester,	Westtown (28 days),	350	...	...	...	54·[illegible]	80	10	25	31	63·6	44·5	19·1	32	10	6	5	...	...	...	...	...	6	15	3	5	W	...	W	Harry Alger.
Clearfield,	Grampian (30 days),*[1]	1,450	...	...	...	47·[illegible]	76	11	13	31	60·0	40·9	19·1	44	2	2	15	...	...	2·62	...	...	6	12	11	7	W	W	SW	Nathan Moore.
Clinton,	Lock Haven,[1]	560	...	...	...	54·[illegible]	83	9	2[illegible]	31	60·7	33·4	27·3	47	2	5	4	...	...	2·07	...	...	9	16	5	15	W	W	W	Prof. J. A. Robb.
Columbia,	Bloomsburg, A— State Normal School,	500	30·05	30·43	29·49	53·[illegible]	79	9	24	31	63·5	4[illegible]	21·0	35	2	9	16, 21	81·8	46·2	1·18	...	...	8	14	8	9	W	...	N	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,[1]	1,200	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Chas. Graves.
Crawford,	Saegertown, A,	1,200	...	...	...	50·[illegible]	88	25	2	31	[illegible]5·5	36·0	29·5	51	11	7	15	...	...	3·00	0·2	...	8	13	9	9	S	...	SW	J. G. Apple.
Cumberland,	Carlisle[1] (19 days),	480	...	...	...	53·[illegible]	85	9	23	31	66·7	42·4	24·3	40	9	6	4, 28	...	...	·97	...	...	4	11	4	4	Calm.	SW	W	J. E. Pague.
Dauphin,	Harrisburg, A,	361	30·13	30·52	29·26	55·[illegible]	82	9	23	31	63·0	47·0	16·0	32	9	4	4	82·0	48·0	3·25	...	...	9	13	7	11	W	W	W	F. Ridgway, Weather Bureau.
Delaware,	Swarthmore, A— Swarthmore College,	190	30·11	30·44	29·29	56·[illegible]	80	9	27	31	64·9	48·2	16·7	29	17	5	23	84·0	4[illegible]·0	3·35	...	...	4	11	15	7	NW	...	NW	Prof. Susan J. Cunningham.
Erie,	Edinboro,*[1]	1,400	...	...	...	50·4	76	11	14	31	...	...	...	...	...	...	...	...	...	...	...	...	...	17	4	10	W	...	...	C. F. S[illegible].
Erie,	Erie, A,	681	30·05	30·30	29·05	54·[illegible]	84	12	[illegible]	31	62·0	46·0	16·0	28	3	4	27	7[illegible]·0	42·[illegible]	3·84	...	...	10	12	7	12	S	S	S	P. W[illegible]d, Weather Bureau.
Fayette,	Uniontown[1] (26 days),	1,000	...	...	...	56·[illegible]	81	12	29	17	66·7	45·7	21·0	35	2	5	15	...	...	3·22	...	...	6	17	3	6	SW	SW	SW	Wm. Hunt.
Franklin,	Chambersburg[2] (29 days),	618	...	...	...	54·[illegible]	80	9	25	30, 31	62·9	45·8	17·1	4	9	2	5	...	...	3·85	...	...	5	19	3	7	NE	SW	SW	G. W. Ludwig.
Fulton,	McConnellsburg,[1]	875	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T. F. Sloan.
Huntingdon,	Huntingdon, A— The Normal College,	650	...	...	...	52·5	82	9	21	31	66·4	38·7	27·7	44	2	10	15	...	...	3·70	...	...	8	15	3	13	W	...	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker.
Juniata,	Kilmer,[3]	475	...	...	...	53·[illegible]	75	24	28	31	...	...	...	...	...	...	...	...	...	4·41	...	...	7	13	8	10	W	...	...	R. J. M[illegible]ckey.
Lancaster,	Lancaster, A— Franklin and Marshall College,	413	30·14	30·51	29·27	54·[illegible]	82	9	24	31	64·7	43·9	20·8	36	18	6	4	86·0	48·3	3·30	...	...	9	19	4	8	W	...	W	W. E. Bushong.
Lawrence,	New Castle,[1]	932	...	...	...	52·[illegible]	82	11, 12	19	31	63·5	35·6	27·9	45	2	7	15	...	...	4·59	...	...	6	13	5	13	SE	S	SW	Wm. T. Butz.
Lebanon,	Lebanon, A,	458	30·14	30·52	29·08	53·3	80	9	22	31	64·4	42·2	22·2	38	9	8	4	91·4	43·4	3·95	...	...	8	14	10	7	NW	...	NW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,[1]	520	...	...	...	53·2	75	9	25	31	61·4	45·7	15·7	31	17	2	4	...	...	3·26	...	...	10	14	9	8	NE	SW	NE	Dr. M. H. Boye.
Luzerne,	Drifton (26 days), A,	1,683	30·12	30·57	29·24	51·[illegible]	76	11	22	30	64·7	39·0	25·7	38	2, 27	7	4	79·0	47·0	3·36	...	...	4	15	6	5	...	...	...	J. R. Wagner.
Luzerne,	Wilkes-Barre, A,	575	...	...	...	53·[illegible]	82	9	21	31	66·2	41·[illegible]	24·9	43	11, 12	7	15	...	...	1·70	...	...	6	16	6	9	W	...	W	A. W. Betterly.
McKean,	Smethport, A,	1,500	...	...	...	50·[illegible]	81	11	17	31	63·6	37·5	26·1	50	11	6	4	...	...	3·65	2·0	...	6	11	6	14	SW	...	SW	Armstrong & Brownell.
Montgomery,	Pottstown,	150	...	...	...	55·5	81	9	27	31	65·4	45·7	19·7	36	9	4	4, 23	74·6	44·6	3·13	T	...	6	23	2	6	NW	W	E	Charles Moore, D.D.S.
Montgomery,	Skippack, A (25 days),	...	...	...	...	54·[illegible]	88	24	25	31	66·7	42·3	24·4	37	9	6	23	...	...	2·[illegible]0	...	...	4	14	6	5	W	...	W	B. W. Dambly.
Northampton,	Easton[1]— Lafayette College,	325	...	...	...	53·0	75	9	24	30	61·5	43·2	1[illegible]·3	28	9, 17	6	23	...	...	2·62	...	...	5	...	...	...	...	...	...	J. W. Moore.
Perry,	Aqueduct (Logania),*[1]	367	...	...	...	55·[illegible]	83	9	22	31	66·1	44·6	21·5	37	9	3	27	...	...	3·29	...	...	11	16	7	8	NW	...	...	Ric[illegible] Cal[illegible].
Philadelphia,	U. S. Weather Bureau, A,	117	30·12	30·53	29·31	58·[illegible]	80	9	33	31	65·4	49·9	15·5	26	17	4	16	73·0	46·0	3·32	...	...	9	13	10	8	NW	NW	NW	L. M. Dey, Weather Bureau.
Philadelphia,	1529 Centennial Avenue, A,	120	30·12	30·53	29·31	57·4	80	9	30	31	65·6	49·2	16·4	26	17	5	4	77·0	47·2	3·56	...	...	9	15	9	7	...	...	...	John Comly.
Philadelphia,	3311 Locust Street, A,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ralph L. Paddock.
Pike,	Blooming Grove,*[1]	...	...	...	...	49·4	76	11	20	30, 31	...	...	...	...	...	...	...	...	...	1·51	...	...	5	...	...	...	...	...	...	John Grathwohl.
Schuylkill,	Girardville[1] (29 days),	1,000	30·05	30·45	29·16	52·1	78	2, 9	28	31	62·3	43·2	19·1	36	9	7	16	...	...	3·87	...	...	8	14	11	4	W	NW	NW	F. C. Wagner.
Snyder,	Selins Grove, A,	455	30·07	30·43	29·23	52·4	75	2	26	30, 31	67·1	37·7	29·4	41	2	12	23	91·8	47·5	4·21	...	...	8	3	21	7	SW	...	SW	J. M. Boyer.
Somerset,	Somerset,[1]	2,250	...	...	...	49·[illegible]	81	10	18	31	63·4	38·7	24·7	42	10	10	15, 24	90·3	47·5	3·01	...	...	7	13	...	18	NW	SW	NW	W. M. Schrock.
Tioga,	Wellsboro,*[1]	1,327	...	...	...	46·0	74	9	20	31	58·1	35·3	21·8	41	2, 18	1	4	...	...	2·88	1·0	...	9	11	8	12	S	...	S	H. D. Dem[illegible].
Union,	Lewisburg, A,	450	30·12	...	...	52·6	82	9	22	31	64·6	40·6	24·0	45	9	7	15	92·0	48·6	3·20	...	...	10	10	10	11	S	...	S	Prof. W. G. Owens.
Warren,	Columbus,	1,410	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Wm. Loveland.
Wayne,	Dyberry,[1]	1,100	...	...	...	48·1	79	9	15	31	61·8	37·4	24·4	49	11	2	23	...	...	2·17	T	...	5	11	12	8	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,[1]	1,300	...	...	...	50·[illegible]	73	9	19	13	60·0	40·5	19·5	34	18	4	23	...	...	1·99	...	...	6	...	...	...	...	...	...	John Torrey.
Wayne,	(Salem Corners) Hamlinton,[1]	1,600	...	...	...	48·7	76	12	19	31	63·9	40·5	2[illegible]·4	38	11	5	23	...	...	2·70	...	...	7	11	11	9	W	SE	W	T. E. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,*	1,420	...	...	...	55·6	78	11	35	30	...	...	...	...	...	...	...	...	...	2·92	...	...	9	...	...	...	...	...	...	Murray Forbes.
Westmoreland,	Ligonier,	1,750	...	...	...	51·5	87	11	18	31	66·0	37·4	28·6	53	11	4	14	...	...	2·98	...	...	5	20	...	11	...	...	...	J. T. Ambrose.
Wyoming,	South Eaton, A,	660	...	...	...	52·0	79	9	21	31	62·4	41·5	20·9	39	11	6	4	...	...	1·88	...	...	9	12	7	12	NW	...	NW	R. M. Hall.
York,	York, A,	385	30·07	30·48	28·99	54·[illegible]	82	9	22	31	65·0	43·4	21·6	40	9	7	14	86·1	48·8	3·03	...	...	8	18	5	8	NW	...	NW	Mrs. L. H. Grenewald.

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, $7 + 2 + 9 + 9 \div 4$. [2] Mean of $8 + 8 + 2$. [3] Mean of $7 + 7 + 2$. Absence of numerals indicates that mean of temperature is from maximum and minimum readings.

3

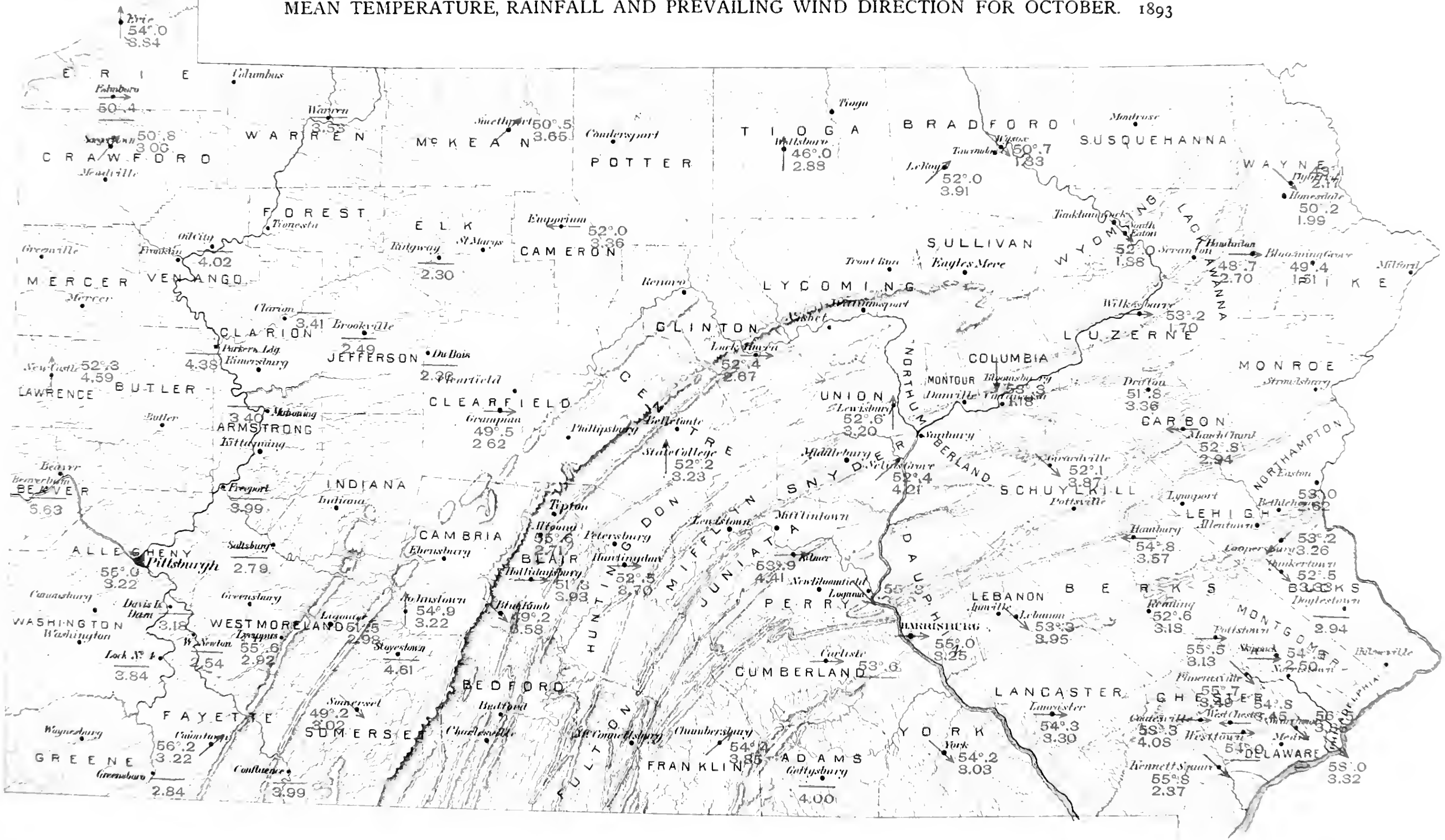
PRECIPITATION DURING OCTOBER, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
[illegible] Grove,				'02			'24							'14										'62				'49				1'51
Brewers Lock,					'03		'16						'40	1'02									1'04	'18				'59				3'42
Coatesville,				'68		'06							1'20	'19								'16	'57	'18			'77	'27				4'08
Coopersburg,				'68		'04	'24						'07	'75								'02	'64	'01			'50	'31				3'26
Doylestown,							'14						'39	'61									1'33				'03	'44				2'94
Dyberry,							'26						'65	'38									'55				'33					2'17
Easton,					'03		'30							'56										'60				'81				2'62
Forks of Neshaminy,				'10			'20						'35	'48								'10	1'47	'02			'09	'54				3'35
Frederick,				'05			'13						'30	'58								'10	'66				'40	'23				2'45
Hamburg,				'28		'32							'82	'67									'55				'73					3'57
Honesdale,					'27								'89		'05								'37				'40		'01			1'99
Kennett Square,				'08		'03	'19						'45	'03								'24	'76	'02			'26	'31				2'37
Lansdale,							'09						1'14	'33									1'35				'80					3'71
Mauch Chunk,							'45						'46	'62									'74	'10			'36	'21				2'94
Ottsville,				'04			'26						'50	'60									'94	'02			'22	'50				3'08
Philadelphia, a†				'02			'56						'14	'21								'15	1'12	'01			'27	'84				3'32
Philadelphia b,				'02		'01	'38						'23	'49								'22	1'44				'32	'45				3'56
Phoenixville,				'06			'13						'42	'94								'18	1'02	'03			'24	'46	'01			3'49
Point Pleasant,							'38						'41	'60								'05	1'23	'02			'15	1'24				4'08
Pottstown,				'05		'10							1'63									'53	'23				'59					3'13
Quakertown,				'09		'07	'17							1'35								'05	'68					'92				3'33
Reading,				'14		'01	'15						'75	1'25									'40	'01			'30	'16	'01			3'18
Salem Corners,					'07		'22							1'58		'06							'40	'09				'28				2'70
Sellersville,			'14										'77	'61									'78				'45	'44				3'19
Skippack,						'33				*	*		1'13	'01					*		*		1'03			*	*					2'50
Smith's Corner,				'02			'35						'59	'69								'03	1'23				'12	1'29				4'32
Swarthmore,				'10			'20																3'00				'05					3'35
West Chester,				'04		'08	'10						1'15	'31								'30	1'04				'15	'25				3'45
Westtown,																																..
Susquehanna Basin.																																
Altoona,				'72	'02									1'40	'04	'02					'19		'02	'03			'05	'22				2'71
Aqueduct,																																..
Bloomsburg,				'11		'02	'09									'01					'07		'51				'22	'15				1'18
Blue Knob,				'97		'07							1'97	1'44		'10					'48	22	'23	'60			'43	'07				6'58
Carlisle,				'60			'20							*	*	*	*	*	*	*	*	*	*	*	*		'11	'06				'97
Drifton,	*						*							'98	*			'38				*	1'30					'70	*			3'36
Emporium,				'50		'03	'31						'31	'16	'12	'11							'01	'01			'35	'09	'04			3'36
Gettysburg,				'15	'58		'05						1'90										'93	'03				'34				4'05
Girardville,				'10		'18	'10						1'38	1'23	*							*	'44				'36	'18				3'87
Grampian,				1'02		'24							'38	'62							'10					*	'26					2'62
Harrisburg,†				'54			'14						'55	'75								'06	'65	'07			'32	'17				3'25
Hollidaysburg,				'71			'04						1'46	'74							'26	'09	'13				'42	'08				3'93
Huntingdon,				'99									'50	1'31							'15	'10		'06		'09	'50					3'70
Kilmer,		*		'40									2'20	'95					'05			'10	'42				'29					4'41
Lancaster,				'17		'03	'08						'96	'92								'07	'64	'07			'36					3'30
Lebanon,				'30			15						'55	1'82									'56	'15			'29	'13				3'95
Le Roy,				'20									'15	2'60	'10	'01							'17	'08			'15	'42	'03			3'91
Lewisburg,				'19		'07	'04						'20	1'45					'10			'35	'32				'36	'12				3'20
Lock Haven,				'24	'03								'77	'78									'16	'16			'22	'30	'01			2'67
Selins Grove,							'11						'11	1'85							'07	'11	'72				'22	1'02				4'21
South Easton,				'12	'02		'12						'15	'60									'45	'02			'25	'15				1'88
State College,				'58									'73	1'14	'01						'04	'01	'15	'02			'48	'07				3'23
Wellsboro,				'10									'08	1'95	'10								'05	'05			'15	'25		'15		2'88
Wilkes-Barre,				'08			'11							1'14													'15	'21		'01		1'70
Wysox,				'33									1'38	'02									'11			'06	'43					1'33
York,				'44			'08					'78	1'13									'06	'34				'08	'12				3'03

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,	'02			'79			'40							3'44	'14						[illegible]						[illegible]	[illegible]	[illegible]			[illegible]
Brookville,				'79	'12		'21							'54	'47	'07								'03			[illegible]	'14		[illegible]		[illegible]
Clarion,				1'03	'07		'05							1'12	'30	'12					'05						[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Columbus,																																
Confluence,				1'22	'09		'01							1'16	'35						'67		'05	'05			[illegible]	[illegible]	[illegible]			[illegible]
Davis Island Dam,	'05			'73			'04							1'58	'13						'30			[illegible]			[illegible]	[illegible]	[illegible]			[illegible]
DuBois,				'66			'39							'38	'38	'09								'03			[illegible]	[illegible]	[illegible]			[illegible]
Freeport,	'11			'80	'06		1'18							1'02	'07	'03					[illegible]						[illegible]	[illegible]	[illegible]			[illegible]
Greensboro,	'02			'82	'08		'06							'55	'31						'30			[illegible]			[illegible]	[illegible]	[illegible]			[illegible]
Immel Reservoir,				'86			'55							'60						'45			[illegible]	'03			[illegible]		[illegible]			[illegible]
Indiana,																																
Johnstown,				'82									'55	[illegible]	'04	'02					'40		'03	'07			[illegible]	[illegible]	[illegible]			[illegible]
Ligonier,				1'08									80	'20													[illegible]	[illegible]				[illegible]
Lock No. 4,	'02			'78	'10		'33							1'84	'19						'39						[illegible]	[illegible]	[illegible]			[illegible]
Mahoning,				1'11	'08					'10				'98	'39	'03					'19			'03			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Meadville,																																
New Castle,				'75										[illegible]						'15			'20				[illegible]	[illegible]				[illegible]
Oil City,				'94	'01		'07							1'45	'20	'20					'09						[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Parker's Landing,				'95	'09									1'67	'40	'10					'30			[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]
Pittsburg,†	'02			'71		'20							1'01	'33	'05					[illegible]			'01				[illegible]	[illegible]				[illegible]
Ridgway,			'61	'04		'20							'82	40												'09	[illegible]		[illegible]			[illegible]
Saegertown,				'02									'21	1'02	1'22											[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
Saltsburg,				1'00	'08		'44							'37	'24						'27			[illegible]			[illegible]	[illegible]	[illegible]			[illegible]
Smethport,				'45									1'75	'50	'25												[illegible]			[illegible]		[illegible]
Somerset,				1'12									'40	'42						[illegible]	'05		'10				[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Stoyestown,					'91	'29	'39							'96	'37	'14					'75		'12	[illegible]		[illegible]	*	*	*	*	*	[illegible]
Uniontown,				1'12			'04						'24	'48						'79						[illegible]						[illegible]
Warren,				'78	'09		'01							1'14	54	'14											[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
West Newton,	'07			'77	'15		'26							'64	'14						[illegible]			[illegible]			[illegible]	[illegible]	[illegible]			[illegible]
Potomac Basin.																																
Chambersburg,				'56									1'96				*			'30			[illegible]				[illegible]	*				[illegible]
McConnellsburg,																																
Lake Basin.																																
Erie,†				'69			'05					'68	1'62	'20												[illegible]	*	[illegible]	[illegible]	[illegible]		[illegible]

† U. S. Weather Bureau Stations. * Missing.

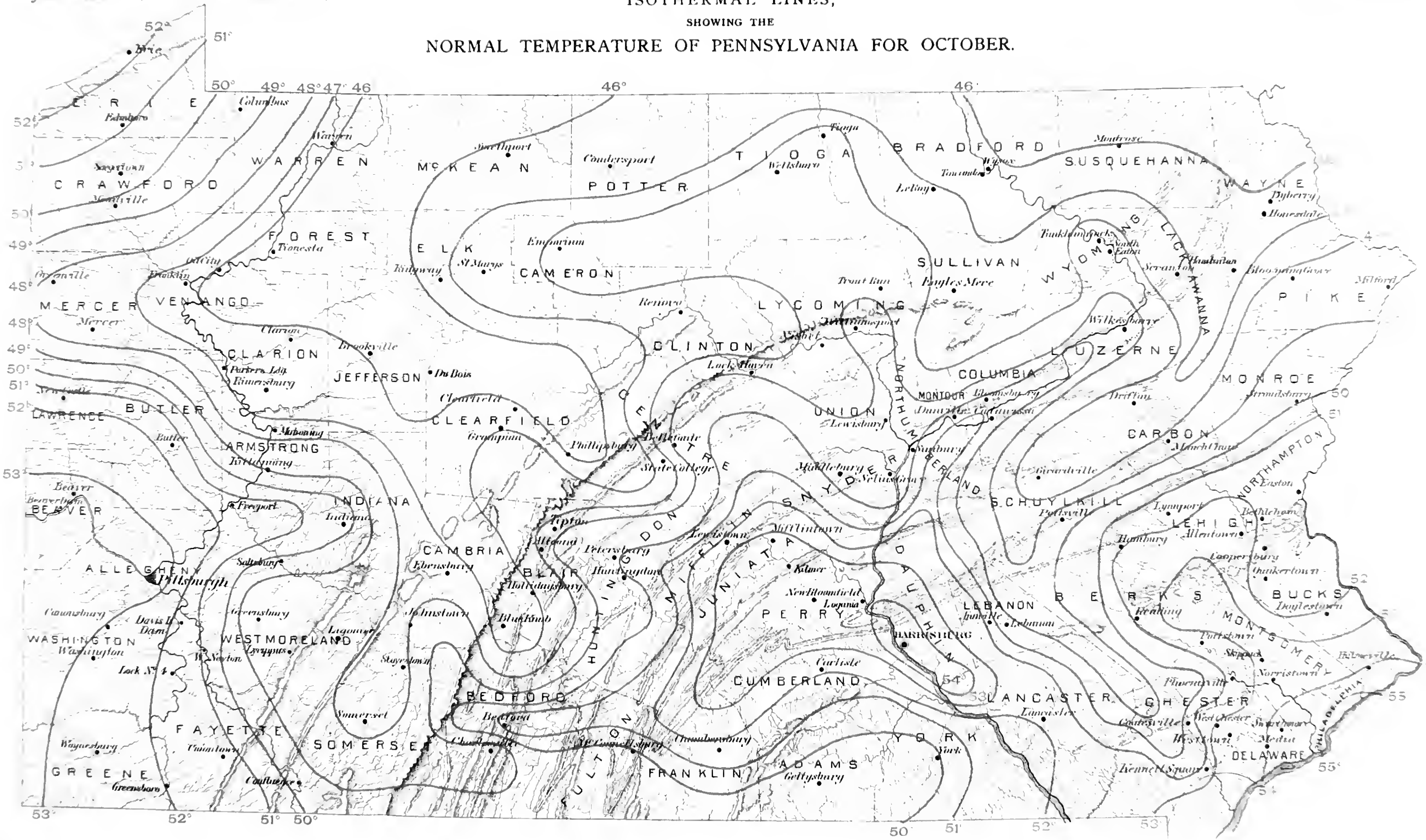
MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR OCTOBER. 1893



ISOTHERMAL LINES,

SHOWING THE

NORMAL TEMPERATURE OF PENNSYLVANIA FOR OCTOBER.



The least were Bloomsburg, 1·18; Wysox, 1·33; Blooming Grove, 1·51, and Wilkes-Barre, 1·70 inches.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: rainy days, 8; clear days, 14; fair days, 8; cloudy days, 9.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 14th; Forks of Neshaminy, 27th; Emporium, 24th; Wellsboro, 24th.

Hail.—Blue Knob, 28th.

Snow.—Blue Knob, 15th, 16th, 28th, 29th; Le Roy, 16th, 19th, 30th; Forks of Neshaminy, 30th; Johnstown, 29th; Emporium, 29th, 30th; Mauch Chunk, 30th; Coatesville, 30th; Bloomsburg, 29th; Saegertown, 28th; Coopersburg, 30th; Wilkes-Barre, 30th; Smethport, 28th, 30th; Pottstown, 30th; *Philadelphia* [Centennial Avenue], 30th; Girardville, 29th, 30th; Selins Grove, 29th; Wellsboro, 30th; Dyberry, 29th, 30th; Salem Corners, 16th; Ligonier, 29th; Phœnixville, 29th.

Frost.—Pittsburgh, 18th, 19th, 30th; Blue Knob, 1st, 2d, 8th, 10th, 15th, 16th, 17th, 18th, 19th, 20th, 25th, 26th, 27th, 28th, 29th, 30th, 31st; Hollidaysburg, 1st, 2d, 17th, 18th, 26th, 30th, 31st; Wysox, 1st, 11th, 16th, 17th, 18th, 19th, 26th, 31st; Le Roy, 16th, 17th, 26th, 29th, 30th, 31st; Forks of Neshaminy, 11th, 16th, 17th, 20th, 26th, 30th, 31st; Emporium, 2d, 3d, 10th, 11th, 17th, 18th, 19th, 26th, 31st; Mauch Chunk, 17th, 18th, 26th, 30th, 31st; State College, 1st, 2d, 17th, 18th, 19th. 26th, 31st; Coatesville, 1st, 11th, 17th, 18th, 30th, 31st; Kennett Square, 1st, 11th, 12th, 15th, 18th, 19th, 20th, 23d, 29th, 31st; Westtown, 17th, 18th, 30th, 31st; Grampian, 2d, 17th, 18th, 31st; Lock Haven, 11th, 17th, 18th, 19th, 20th, 26th, 30th, 31st; Bloomsburg, 17th, 18th, 26th, 30th, 31st; Saegertown, 1st, 2d, 3d, 9th, 11th, 12th, 18th, 19th, 27th, 28th, 31st; Carlisle, 1st, 30th, 31st; Harrisburg, 1st, 17th, 18th, 30th, 31st; Edinboro, 29th, 31st; Huntingdon, 2d, 31st; Lancaster, 17th, 26th, 30th, 31st; Lebanon, 1st, 17th, 18th, 26th, 30th, 31st; Coopersburg, 30th, 31st; Drifton, 16th, 17th, 18th, 28th, 30th; Wilkes-Barre, 9th, 17th, 26th, 31st; Easton, 1st, 17th, 18th, 26th, 30th, 31st; *Philadelphia* [Weather Bureau], 17th, 18th, 20th, 26th, 30th, 31st; [Centennial Avenue], 17th, 18th, 20th, 26th, 30th, 31st; Girardville, 8th, 9th, 11th, 12th, 16th, 17th, 18th, 20th, 26th, 28th, 29th, 30th, 31st; Somerset, 1st, 2d, 3d, 8th, 17th, 18th, 19th, 28th; Wellsboro, 1st, 2d, 8th, 11th, 17th, 18th, 19th, 29th, 30th, 31st; Lewisburg, 1st, 2d, 17th, 25th, 26th, 29th, 30th, 31st; Dyberry, 1st, 8th, 11th, 12th, 17th, 18th, 19th, 26th, 30th, 29th, 31st; Honesdale, 1st, 11th, 17th, 18th, 19th, 26th, 29th, 30th, 31st; Salem Corners, 17th, 26th, 30th, 31st; York, 1st, 17th, 18th, 26th, 30th, 31st; Phœnixville, 17th, 18th, 26th, 30th, 31st; Skippack, 1st, 2d, 12th, 16th, 17th, 18th, 20th.

Sleet.—Blue Knob, 21st.

Aurora.—Le Roy, 2d; Selins Grove, 24th; Salem Corners, 1st, 3d, 5th, 8th.

Coronæ.—Emporium, 26th; Lebanon, 25th, 30th.

Solar Halo.—Philadelphia [Centennial Avenue], 12th; Wellsboro, 22d; Dyberry, 26th.

Lunar Halo.—Forks of Neshaminy, 19th; State College, 24th; Lancaster, 20th; Lebanon, 20th; Somerset, 21st; Wellsboro, 26th; Salem Corners, 20th,

Meteors.—State College, 31st; Philadelphia [Centennial Avenue], 17th, 30th.

Parhelias.—Dyberry, 26th.

DECEMBER WEATHER.

From United States Weather Bureau Records.

The following data, compiled from the records of observations taken during the length of time given at each station, show the average and extreme conditions during that time, and also the range within which weather variations may be expected to keep in any future December.

	Philadelphia. (22 years.)	Pittsburgh. (23 years.)	Erie. (20 years.)
Mean or normal,	35°	34°	32°
Warmest December, Average,	1889 44°	1889 46°	1889 41°
Coldest December, Average,	1876 25°	1876 23°	1876 22°
Highest temperature recorded, Date,	70° 4th, 1873	73° 9th, 1885	70° 29th, 1889
Lowest temperature recorded. Date,	Minus 5° 30th, 1880	Minus 9° 30th, 1880	Minus 11° 30th, 1880
Average date of first "killing" frost,	October 28th	October 21st	October 15th
Average precipitation (inches),	2·71	2·85	3·28
Average number of days with ·01 inch or more,	10	15	20
Greatest monthly precipitation, Date,	5·06 1887	5·64 1890	6·44 1881
Least monthly precipitation, Date,	0·83 1877	0·83 1876	0·75 1876
Greatest amount in 24 hours, Date,	2·23 16th and 17th, 1888	2·35 16th and 17th, 1890	1·34 9th, 1878
Greatest amount snowfall in 24 hours, Date,	6·00 17th, 18th, 1887	16·50 16th and 17th, 1890	5·00 17th, 1884
Average number clear days, Partly cloudy, Cloudy,	8 11 12	3 12 16	2 7 22
Prevailing direction of wind,	NW.	W.	SW.
Highest velocity, miles per hour, Date,	63 10th, 1878	40 16th, 1876	52 1875, 1876

in

delp

rr

CKET